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Typha Control and Sedge/Grass Meadow Restoration on a Lake Ontario Wetland

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by Alex Czayka

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Biographical Sketch

Alex Czayka, a native of Jefferson, OH, attended Jefferson Area high school where he graduated in 2005. While in high school, Alex did post-secondary education at Kent State University (Ashtabula Campus). Alex attended college at Kent State University (Kent Campus) where he graduated in four years with a bachelor's degree in organismal biology. While at Kent State, Alex researched central mottled sculpin behavior as part of an independent study under Dr. Mark Kershner. He then attended graduate school at the State University of New York College at Brockport were he pursued his master's degree in wetland ecology under the supervision of Douglas Wilcox, Ph.D.

Dedication:

I dedicate this paper to my parents, Michael and Robin Czayka, for all their guidance in life, and for encouraging me and keeping me focused throughout the thesis process.

ABSTRACT

To identify control techniques for cattails (*Typha angustifolia* and the hybrid *Typha* x *glauca*) in a Lake Ontario drowned-rivermouth wetland, multiple physical and chemical treatment techniques were implemented over two years at Kents Creek, New York. Treatments included cutting (C), spraying (S) glyphosate (Rodeo) onto cut stalks, tilling (T) rhizomes, and wicking (W) cattail re-sprouts later in the growing season (August). Each treatment technique had year options; for example, the cut treatment could be applied in year 1 or in both years 1 and 2 (C1 or C12). All possible treatments yielded 24 treatment combinations, plus two control plots; these were randomly assigned to each of the five treatment replicates established in equivalent stands of cattail. Vegetation sampling occurred in early summer (late June) and again in late summer (August) before treatment in both years. Cattail stem counts and species percent cover data were collected to analyze the effects of the treatments. Environmental variables (soil moisture, sediment depth, water-table elevation, soil organic matter, and bulk density) were measured to assist in the explanation of treatment success and differences observed among replicates. In addition to looking at the direct effects the treatments had on cattails, I assessed how the treatments affected the growth and expansion of sedge/grass meadow community species (*Carex lacustris* and *Calamagrostis canadensis*).

Treatments combinations C1W1, C1SW1, C1WT, C12SW1, C12W1T, and C12SW1T significantly reduced cattail stem counts from June 2010 to August 2011. The most important treatment technique was the wick (W) treatment,

which was implemented in August; it was included in every successful treatment for reducing cattails. The C12W1T treatment significantly reduced cattail stem counts the most (mean of 15.9 stems per plot), while treatments C12SW1T (12.9) and C12SW1 (12.2) also caused large reductions in *Typha* stems. Eight treatments significantly increased the amount of *C. lacustris*, including C1, C1W1, C1SW1, C1WT, C1SW1T, C12W1, C12SW1, and C12W1T. Five treatments that significantly reduced *Typha* stems also significantly increased *C. lacustris* cover. Overall, *C. lacustris* increased an average of 18% for any plot that had treatments applied. Treatment replicate 3 had some significantly different environmental variables that likely led to more successful treatments. Replicate 3 was positioned at a slightly higher elevation compared to the other replicates, leading to lower soil moisture, which helps control cattails. Although application of the wick treatment in August was the most important treatment method, addition of other treatments earlier in the year increased stress on cattails and led to increased reductions. Reduction of cattails also led to increased growth of *Carex lacustris* if *C. lacustris* was present before treatments were implemented. For management implications, I suggest using the cutting (early summer) and wicking treatments (late summer), as these two treatments were the most effective at reducing *Typha* stems. If funds are available, the tilling treatment combined with cutting and wicking, could be implemented, as it helped increase stress on *Typha* and led to increased stem reductions.

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INTRODUCTION

As a result of lake-level regulation and lack of low water periods, Lake Ontario now contains few areas with large stands of native sedge/grass meadow (Wilcox et al. 1992, 2005, 2008, Wilcox and Meeker 1995). Kents Creek, a drowned river mouth wetland located near Cape Vincent, New York is one of the few remaining wetland sites that contain relatively large areas of sedge/grass meadow. However, invading cattail (*Typha*) continues to outcompete sedge/grass meadow species at higher elevations. The International Joint Commission is considering implementing a regulation plan with a more natural hydrologic cycle on Lake Ontario; if this action is taken, it will not likely control *Typha* in a reasonable time period without help (Wilcox and Xie 2007, 2008). This study implemented various methods to control *Typha* in hopes of finding a successful technique that could be used in wetlands throughout Lake Ontario. The response of sedge/grass meadow species to the control techniques was examined to determine if treatments successful at reducing *Typha* also increased the areal coverage of sedge/grass meadow species. In combination, environmental variables were compared at the replicate level (e.g., soil moisture, sediment depth, soil bulk density) to help understand the ecology of *Typha* in a regulated hydrological system.

Water levels/Regulation

Water-level fluctuations on the Laurentian Great Lakes occur at several levels, from wind-driven seiches that occur daily to seasonal, annual, and decadal fluctuations that reflect the effects of the annual water budget and climatic fluctuations (Baedke and Thompson 2000, Johnston et al. 2004, Wilcox et al. 2007). Longer-term, climate-driven fluctuations on lakes Michigan and Huron follow a quasi-periodic ~33 year cycle superimposed on a larger ~160 year cycle (Thompson and Baedke 1997, Baedke and Thompson 2000). Historically, Lake Ontario likely had a similar climate-driven system with a range in fluctuation of 1.5 m. Recorded lake levels from 1860 to 1960 show a pattern similar to that of the upper lakes (Figure 1), but no longer-term data exist (Wilcox et al. 2005, Wilcox et al. 2008). Recorded levels on Lake Ontario have ranged from a maximum of 75.77 m in June 1952 to a minimum of 73.76 m in November of 1934—a total range of 2.02 m (Wilcox et al. 2007). The operation of the St. Lawrence Seaway began around 1960; since then, Lake Ontario water-levels have been controlled by the Moses-Saunders hydroelectric dam located between Massena, New York and Cornwall, Ontario (Wilcox and Xie 2007). Lake Ontario is now controlled by regulation plan 1958D with deviations (1958DD) imposed by the International Joint Commission (Carpentier 2003); this plan was designed to favor interest groups such as hydroelectric power facilities and the shipping industry. Regulation plan 1958DD has reduced water-level fluctuations on Lake Ontario to roughly half of what they were pre-regulation (1.5 m to 0.7 m), with a mean annual variation of 0.52 m. According to this plan, lake levels should not go above or below the range of 74.49 m to 75.01m (Wilcox et al. 2005, Wilcox et al. 2007).

The major problem with the current regulation plan (1958DD) is that it attempts to reduce lake levels during high water-supply periods and raise lake levels during low supply periods (Wilcox et al. 2008). Water levels are held higher through summer and then reduced in fall through early spring to create capacity for spring runoff and to prevent ice damage. During years of low water supply that should result in low lake levels during the summer, water is held back to maintain higher levels (Wilcox and Xie 2008). Studies conducted during the International Joint Commission (IJC) Great Lakes Water Levels Reference Study that began in the late 1980s showed the connection between loss of hydrologic variability and alterations in wetland plant communities (Wilcox et al. 1992, Wilcox and Meeker 1995).

Fluctuations in water levels are necessary to maintain and renourish coastal wetland plant communities. Great Lakes plant community dynamics are driven primarily by the quasi-periodic lake-level cycles related to climatic changes (Wilcox 2004, Wilcox et al. 2007). These fluctuations are a natural form of disturbance in the Great Lakes; natural disturbance promotes vegetation diversity, as discussed by Grubb (1977), Connell (1978), Grime (1979), Huston (1979), White (1979), and Keddy and Reznicek (1986). Periodic high lake levels kill dense emergents and invading shrubs and trees. Low lake levels allow less competitive understory species to grow from the seed bank (Keddy and Reznicek 1986, Maynard and Wilcox 1997). Individual plant species require specific water depths to emerge, grow, and replenish the seed bank. These differences in physiological affinities, tied with the hydrologic cycle, account for the plant diversity that comprises Great Lakes coastal wetlands. (Sculthorpe 1967, Spence 1982, Kozlowski 1984, Wooten 1986, Hejny and Hroudova 1987, Keddy 2000)

Alteration of natural water-level cycles through regulation affects wetland community dynamics, productivity, and function (Keddy 2002, Nilsson and Svedmark 2002). Saturated soils in wetlands that have been altered hydrologically are more likely to be invaded because they undergo changes in soil chemistry that make nutrients more available for plant uptake (Boers and Zedler 2008). Higher, stable water levels cause soils to change from oxic to anoxic (Ponnamperuma 1972). Stabilized water levels prolong anoxic periods that release phosphorus (P) into soil solution due to reduction of iron oxides and solubilization of sorbed P (internal eutrophication) (Young and Ross 2001). Internal eutrophication allows plants to take up nutrients that had previously been locked up in wetland sediments (Koerselman et al. 1993). Prolonged flooding favors *Typha* x *glauca*, a highly invasive hybrid cattail that is able to take up more P when water levels are stabilized. The increased uptake of P, a vital nutrient to the growth and reproduction of the plant, gives *T.* x *glauca* a competitive advantage, allowing it to invade new areas (Boers and Zedler 2008). Woo and Zedler (2002) showed that *Typha* spp. were better able to take advantage of increased nutrient availability than the native species they displace. Non-natural water levels also can lead to changes in productivity among wetland plants. In five years of sustained inundation in 10 wetlands in Manitoba, *T.* x *glauca* increased above-ground biomass from 7 to 160 g/m^2 when the above-ground biomass of all other macrophytes decreased from 295 to 140 g/m^2 (van der Valk 2000). While *Typha* favors moister areas, sedge/grass meadow species are better adapted to drier conditions, which gives them a competitive advantage when lake levels are low (Wilcox et al. 2008).

Wilcox and Nichols (2008) demonstrated that water-level fluctuations are an important driving force in the development of wetland vegetation in the Great Lakes. Alternating flooded/dewatered conditions are important in generating diversity in the plant community (Keddy 2000, van der Valk 2000). Wilcox and Nichols (2008) showed that wetlands that had been flooded and then dewatered contained more species than areas that had been permanently flooded in the seiche zone, or briefly flooded. Grosshans et al. (2004) concluded that lack of low water levels on regulated Lake Winnipeg was responsible for alterations of vegetation at Netley-Libau Marsh. Regulation of lake levels on six Lake Manitoba wetlands allowed *Typha* to double in area of dominance (33% to 60%) within 20 years of water-level stabilization (Shay et al. 1999). At an experimental site in Illinois, *T.* x *glauca* cover was 80% under stabilized water levels, and species richness was one-third that of drier sites with infrequent inundation and 10% cover of *T.* x *glauca* (Boers et al. 2007). These studies confirm the importance of natural water-level fluctuations in driving wetland plant community dynamics.

Native flora and fauna are adapted to the hydrologic cycle and depend on it to survive. For example, *Carex stricta* (tussock sedge) can withstand both low lake levels via their drought tolerance and high lake levels via their tussock-forming nature (Yetka and Galatowitsch 1999). Northern pike (*Esox lucius*) depend on elevated water levels in early spring to access shallowly flooded sedge/grass meadows to spawn (Morrow et al. 1995). It is no surprise that these two key organisms of Great Lakes coastal wetlands that depend on periodic changes in lake levels are suffering in Lake Ontario. The low lake levels that favor *C. stricta* do not occur any more, due to regulation. Northern pike not only rely on elevated water levels during the spring, but also on meadow marsh habitat; the lack of natural spawning habitat (meadow marsh) has diminished due to *Typha* invasion (Farrell 2001, Farrell et al. 2006, Cooper et al. 2008, Wilcox et al. 2008). Other species have been negatively affected by the changing environment; muskrats are a keystone species in many wetland communities, and their decline in Lake Ontario has been caused by lake-level regulation (Farrell et al. 2006, Toner 2006). Lake-level regulation results in lower water levels in fall and winter, stranding muskrat 'houses' above the water line (Farrell et al. 2006, Toner 2006), as well as causing ice damage.

Ecology of *Typha*

Typha species are common plants in many freshwater wetlands (Olsen et al. 2009); the Great Lakes are no exception (Vaccaro 2005, Frieswyk and Zedler 2007, Tulbure et al. 2007**)**. Two species of *Typha* can occur in Great Lakes coastal wetlands: *Typha latifolia* and *Typha angustifolia*, as well as the hybrid *Typha* x *glauca*. In general, emergent *Typha* has become increasingly common in wetlands, as both native and invasive taxa expand and colonize new areas in North America (Olsen et al. 2009). *Typha latifolia* (broad-leaved cattail), the native species, has a more robust physiology than *T. angustifolia* (narrow-leaved cattail) or the hybrid. Pollen and herbarium records show that *T. angustifolia* has been expanding its range since the mid 20^{th} century, likely because of the increased disturbance in wetland landscapes (Shih and Finkelstein 2008). *Typha angustifolia* grows along with *T. latifolia* in most of its northeastern range (Grace and Harrison 1986). Sometimes described as an exotic invasive species in North America, pollen and herbarium records suggest that it may have occurred in North America in a restricted range prior to the arrival of European settlers (Shih and Finkelstein 2008). Whatever its origin, *T. angustifolia* has expanded its range much more rapidly than *T. latifolia* (Shih and Finkelstein 2008). *Typha* x *glauca* (hybrid cattail) is a combination of hybrids *T. latifolia* and *T. angustifolia* and can be responsible for displacing large amounts of native wetland vegetation across Lake Ontario (Smith 1967, Wilcox et al 2008).

Typha colonize newly exposed areas primarily by sexual reproduction. A *Typha* inflorescence can contain up to 222,000 seeds (Yeo 1964) that can remain viable in the soil for up to 100 years (Sojda and Solberg 1993). *Typha* also can reproduce vegetatively via rhizomes that form new shoots. Rhizomatous growth is the primary form of reproduction used by *Typha* to overtake and dominate already vegetated areas. One study showed that *Typha* can spread vegetatively over 60 m^2 within two years after germination (Dykjova and Kvet 1978).

The invasive nature of *Typha* has been noted in many areas in North America, but it may be most detrimental in the Great Lakes, especially Lake Ontario. Wilcox et al. (2008) showed that *Typha* expanded in areal coverage from the 1950s to 2001 in all studied wetlands on Lake Ontario. *Typha* expansion resulted in the loss of meadow marsh, a key component to the vegetative dynamics of Lake Ontario. Increasing *Typha* cover and decreasing meadow marsh are likely tied to hydrological modification produced by lake-level regulation;) *T. angustifolia* and *T.* x *glauca* have expanded greatly since regulation of Lake Ontario as a result of increased lake levels and the lack of low lake levels (Wilcox et al. 2008). *Typha* is more flood-tolerant than other native species and often favors moderate flooding (Harris and Marshall 1963, Bedish 1967, Ellison and Bedford 1995, Kercher and Zedler 2004, Boers et al. 2007). *Typha* x *glauca* expands in response to increasing and stable water levels (Waters and Shay 1990, 1992, Shay et al. 1999, Seabloom et al. 2001). In addition, *Typha* can form floating mats near the lake edge that float up and down with lake levels (Wilcox et al. 2008). This adaptation prevents major die-back during high lake-level periods. In Lake Ontario, *T. angustifolia* had its greatest mean percent cover in water deeper than for *T. x glauca* (Wilcox et al. 2005). Both forms of *Typha* invade waterward, but Wilcox et al. (2008) showed that invasion waterward was primarily by *Typha angustifolia*, while expansion of *Typha* into meadow marsh (towards higher elevations) was driven by *T.* x *glauca*. The landward invasion is causing the biggest problems regarding the loss of meadow marsh. Domination by *T.* x *glauca* in Lake Ontario wetlands, as compared to *T. angustifolia* and *T. latifolia*, may be attributed to its plastic response to water-level change (Waters and Shay 1990).

Typha invasion and water-level regulation have led to the diminishing amount of sedge/grass meadow in Lake Ontario wetlands (Wilcox et al. 2008). Earlier reports (Jaworski et al. 1979, Harris et al. 1981, Keddy and Reznicek 1986, Quinlan and Mulamoottil 1987, Painter and Keddy 1992, Maynard and Wilcox 1997) suggested that high lake levels periodically eliminate emergent plants (*Typha*) and subsequent low lake levels allow invasion of *Typha* to lower elevations. Wilcox et al. (2008) concluded that it was actually the lack of low lake levels that was allowing the landward invasion of *Typha* into sedge/grass meadow in Lake Ontario. Therefore, even if treatment techniques are applied and successful at controlling *Typha* in Lake Ontario, wetlands will likely need the help of more natural lake levels to reduce the competitive edge of *Typha***.**

Sedge/grass Meadow Ecology

Calamagrostis canadensis and *Carex* spp. are primary components of sedge/grass meadow (meadow marsh) communities on Great Lakes wetlands (Jaworski et al. 1979, Kelley et al. 1985, Stanley et al. 2000, 2005, Gathman et al. 2005). Two of the more common sedge species that exist in Great Lakes sedge/grass meadow communities are *Carex lacustris* (lake sedge) and *Carex stricta* (tussock sedge). *Calamagrostis canadensis* and many *Carex* species are now less common in Lake Ontario wetlands; from 1959 to 2001, percent cover of meadow marsh at Kents Creek declined from 37.9% to 22.5%, a 40% reduction in 40 years (Wilcox et al. 2008). Currently, *Calamagrostis* has approximately 6-12% mean cover for quadrats sampled in numerous Lake Ontario wetland sites, and *C. stricta* accounted for 3-4% mean cover (Wilcox et al. 2005). *Carex stricta* forms tussocks from old root material that elevate it above the water table. The long roots that extend through the tussock to reach low water levels allow the plant to survive drought conditions, providing a competitive advantage over species less adapted to drought. Established *C. stricta* can tolerate flooding also because tussocks keep portions of the roots above the water (Budelsky and Galatowitsch 2004). *Calamagrostis* is a common associate of *C. stricta* (Costello 1936, Peach and Zedler 2006), although it cannot tolerate prolonged flooding and is found in slightly higher and drier areas of wetlands or on *C. stricta* tussocks (Costello 1936, Keddy and Reznicek 1982, Keddy 1984a, b, Wilcox and Meeker 1991, Kercher and Zedler 2004, Boers et al. 2007). Numerous other *Carex* species contribute to the composition of sedge/grass meadow communities (Kettenring and Galatowitsch 2011).

Water-level regulation and competition from *Typha* seem to be the major factors that have caused the decrease in sedge/grass meadow species (e.g., *C. stricta*, *C. lacustris*, and *C. canadensis).* *Carex stricta* is outcompeted for light by more robust wetland species at both drier and wetter extremes (Wetzel and van der Valk 1998, Budelsky and Galatowitsch 2004). In more saturated areas at lower elevations, *Typha* with intermixed *Phalaris arundinacea* (Wilcox et al. 2005) may provide the competition that ultimately reduces meadow marsh communities (Wetzel and van der Valk 1998, Budelsky and Galatowitsch 2004, Kercher and Zedler 2004, Boers et al. 2007). The height and abundance of live plants and litter from *Typha* inhibit light from reaching shorter, less robust plants. Historically, *Typha* was inhibited at higher elevations due to periodic low lake levels that caused drier soil conditions; current (regulated) water-level fluctuations expand favorable conditions for *Typha* by increasing soil moisture at higher elevations (Wilcox et al. 2008). Three Canadian wetlands that sustained higher water levels beginning in the early 1970s showed loss of meadow marsh (Quinlan and Mulamoottil 1987). Many *Carex* species are less-flood tolerant than *Typha* (Sjoberg and Danell 1983, Squires and van der Valk 1992, van der Valk 1994, Seabloom et al. 2001, Kercher and Zedler 2004). Boers et al. (2007) found that both *C. canadensis* and *C. stricta* were reduced in competition with *T.* x *glauca* under extended and altered hydroperiods. Wilcox et al. (2008) concluded that sustained high water levels beginning in the 1970s (post-regulation) likely resulted in the decline of most sedges in their Lake Ontario sites.

Although sedge/grass meadow communities do not tolerate sustained high water levels, they do respond positively to lower water levels. Wilcox et al. (2008) showed that, in a low water period in the mid-1960s, sedge/grass meadow increased at some Lake Ontario sites. Quinlan and Mulamoottil (1987) demonstrated increases in sedge/grass meadow in their Canadian sites on Lake Ontario during the same time period. The main components of the sedge/grass meadow community, *Carex* spp. and *C. canadensis*, grow vegetatively by tillering and can readily spread into open areas, especially when water levels are lower (natural low water periods) (Costello 1936, Budelsky and Galatowitsch 2004, Stanley et al. 2005).

Control Measures

To understand the control techniques used in this study, the life cycle of *Typha* must be followed step by step through an annual cycle. During winter, *Typha* remains dormant and stores carbohydrate reserves acquired during the prior growing season in the rhizomes. As spring approaches, carbohydrate reserves are used for shoot growth. As spring ensues, energy reserves are used by the plant to form the rest of the above-ground biomass (leaves, stem, and flowers). In early summer (late June), carbohydrate reserves in the rhizomes are at a minimum, as all energy has been put into the above-ground plant. By mid-summer, peak fertilization occurs, and energy reserves in the rhizomes begin to rebuild. In late summer, new *Typha* shoots form for the next growing season, and carbohydrate transport to the rhizomes begins to slow. Fall approaches, causing leaves to senesce and die. Winter ensues, and *Typha* becomes dormant, completing the life cycle (Linde et al. 1976).

Multiple control techniques have been used on *Typha*, but none have addressed *Typha* control on Great Lakes wetlands. One way to control *Typha* is by cutting it in June when storage carbohydrates in rhizomes are at a minimum (Sojda and Solberg 1993). In theory, cutting *Typha* stresses the plant (due to low carbohydrate reserves) and reduces its likelihood of regenerating. Sojda and Solberg (1993) also suggested over-winter flooding of previously cut *Typha* as a successful control method. Flooding *Typha* stems reduces their ability to transport oxygen to the rhizomes, ultimately killing the plant. Other methods include discing and tilling rhizomes (Wilcox and Ray 1989), which disconnects the rhizome network and reduces the ability of *Typha* to survive and reproduce. Aerial spraying of herbicide with glyphosate also can control *Typha*, but time of application and follow-up treatments are important to ensure success (Sojda and Solberg 1993, personal observation 2008, 2009).

Given the problems associated with *Typha* invasion of Lake Ontario wetlands, I investigated numerous treatment measures to control *Typha* and restore sedge/grass meadow. I hypothesized that treatments with all possible techniques (cutting in each of two years, tilling rhizomes, spraying with glyphosate Rodeo in both years, and hand wicking with glyphosate Rodeo) will be the most successful at controlling *Typha* due to the stress put on the plant on multiple occasions. I hypothesized that the same treatments would likely lead to the largest increases in percent cover of sedge/grass meadow species (*Calamagrostis canadensis* and *Carex lacustris*) due to decreased competition from *Typha* and opening of invasion windows (Johnstone 1986).

STUDY SITE

Kents Creek is a drowned river mouth wetland located at the east side of Lake Ontario about 5 kilometers south of Cape Vincent, New York, USA (44° 5'4.03"N, 76°18'16.70"W) (Figure 2). Kents Creek meanders through a large flat basin and into Mud Bay, which connects the creek to Lake Ontario. This site is one of few Lake Ontario wetlands that still contains large areas of sedge/grass meadow (e.g., *Carex stricta*, *Carex lacustris*, *Calamagrostis canadensis*). Most Lake Ontario wetlands are dominated by *Typha;* the difference at this site is that basin morphology has allowed for broad areas of sedge/grass meadow to exist at high enough elevations to avoid long-term wet conditions that enable *Typha* invasion. Due to these rare conditions, there is likely no better place in all of Lake Ontario to study *Typha* control and sedge/grass meadow restoration together. Other common wetland plants at the site include submersed and floating aquatic species (*Ceratophyllum demersum* and *Nymphaea odorata*)*;* emergent species (native *Phragmites australis* and *Polygonum amphibium*); and wet meadow species (*Impatiens capensis* and *Lysimachia thyrsiflora*). The importance of the site for my research is that the large, flat basin of Kents Creek has an obvious transition zone between the existing sedge/grass meadow and invading cattail. Environmental conditions (e.g., soil moisture, water-table elevation, soil composition) were monitored in the transition zone to determine patterns regarding the persistence of sedge/grass meadow and controlling *Typha* in Lake Ontario.

METHODS

To test *Typha* control methods and their effects on sedge/grass meadow restoration, four treatment techniques were implemented at Kents Creek over a two-year period (2010-2011). The primary treatment method was cutting *Typha*, which was done manually using handheld loppers; cut stems were removed from the plots. The cutting treatment was done on 31 June 2011 and 11 July 2010, when storage carbohydrates in rhizomes probably were at their lowest concentrations; both dates fell within a three-week window from one week before to one week after the pistillate spike was lime green and the staminate spike was dark green (Sojda and Solberg 1993). The cutting treatment included cutting in year 1 only, or cutting in both years 1 and 2. The second type of treatment used was the spray treatment. Spraying followed the cutting treatment and was done by spraying glyphosate (Rodeo) on previously cut *Typha* stems using a hand-held sprayer to avoid spraying other plants. This treatment was done only in combination with cutting. Tilling *Typha* rhizomes was another secondary treatment tested in this study; it was done only in the first year. Tilling of *Typha* rhizomes was done manually using a trenching shovel immediately after spraying cut *Typha* stems or cutting only (if spraying was not applied). Tilling was done by jamming the shovel into the ground around every *Typha* stem to disconnect the *Typha* rhizomes. The final treatment technique was wicking. The wick treatment consisted of applying glyphosate (Rodeo) manually to re-sprouting *Typha* plants with a cloth glove. Wick treatments were performed in late August and included not wicking at all, wicking in year 1, or wicking in both years 1 and 2. The different combinations of these techniques resulted in 24 different treatments (Table 1). The 24 treatment combinations came from the 2x2x2x3 block design where each treatment (cutting [n=2], spraying [n=2], tilling [n=2], and wicking [n=3] had multiple treatment options. In addition to the 24 different treatments, two control plots were randomly assigned to each of five treatment replicates (Figure 3).

Five replicates of the 2x2x2x3 design were positioned in near monotypic stands of *Typha*, although these contained some remnant sedge/meadow species, such as *Carex lacustris* and *Calamagrostis canadensis*. Replicate locations were chosen based on similar elevation and relative percent cover of *Typha.* The five treatment locations were on the *Typha* side of the transition area between *Typha* and sedge/grass meadow south of Kents Creek (Figure 2). Before replicates were laid out in May of 2010, standing dead *Typha* was cut with a steel bladed trimmer and removed so that sampling and treatments were not affected by the presence of dead material. Treatment and control plots inside each treatment replicate consisted of 1m x 1m plots that were staked out with PVC pipe and separated from each other by a 1 m working area/buffer (Figure 3).

To measure the success of the treatments, researcher's sampled vegetation twice each year. Vegetation sampling entailed identifying every plant species present in the plot and estimating percent cover of each. In addition, *Typha* stems were counted to show direct effects of treatments. Primary vegetation sampling occurred 10 July 2010 and 30 June 2011, before the treatments were implemented each year. Cutting, spraying, and tilling treatments were applied immediately following primary vegetation sampling. Secondary vegetation sampling occurred in late August each year and entailed recording the same parameters as the primary vegetation sampling (species percent cover and *Typha* stem counts). Following secondary vegetation sampling, the wick treatment was applied to re-sprouting *Typha* plants in applicable treatment plots.

Environmental factors were measured to help understand the underlying variables related to *Typha* control and sedge/grass meadow restoration. Water-table wells were installed at both ends of each treatment replicate to measure the variability in ground-water elevations throughout the growing season (Figure 3). Percent soil moisture measurements were taken with a Dynamax TH20 Moisture Probe in each plot to relate treatment success to moisture levels. In 2010, soil moisture and ground-water elevation measurements were taken weekly from 7 July to 21 August; one measurement was taken 7 on September. In 2011, soil moisture and ground-water elevation measurements were taken bi-monthly from 8 April to 20 May. Due to excessive spring rains and high lake levels in 2011, all five treatment replicates were inundated, causing 100% soil moisture, so readings were not taken in June and July. Measurements continued weekly from 22 July to the end of August, and two readings were taken in September. In the spring of 2010, sediment depths of each treatment and control plot were measured using a soil auger to reach the underlying clay layer. Two surface soil cores with a volume of 298.02 g/cm^3 were collected per treatment replicate in 2010 to measure bulk density and percent soil organic matter. Soil cores were kept in field state (refrigerated) until ready for drying. Bulk density analysis was done using methods described by Grossman and Reinsch (2002). Following bulk density analysis, percent loss on ignition was used to estimate percent organic matter using methods described by Storer (1984).

Because this study was designed to collect data for three years and my data were only collected for two years, eight of the treatment techniques that included the wick treatment in the second year could not be analyzed individually. To analyze the effects of wick treatments in the second year, data will later be collected in 2012. However, these eight treatments were identical to other treatments in the study, since vegetation data were collected before the wick treatment in late summer (C12W12=C12W1), and they were therefore used to increase sample size. The final analysis of *Typha* control and sedge/grass restoration included 16 treatment methods (2x2x2x2). Some paired tests used to analyze data had smaller sample sizes because of a treatment labeling problem in the first year of the study.

STATISTICAL ANALYSIS

Paired t-tests were used on response variables (*Typha* stem counts, *Typha* percent cover, and *C. lacustris* percent cover) to test the significance of individual treatment combinations. Paired treatment techniques were run against each other (e.g., C12WS1 vs C12WS1) based on pre-treatment 2010 samples versus post-treatment 2011samples, and using mean data from all five treatment replicates. Some datasets were non-normal, so the non-parametric alternative, the Wilcoxon signed-ranks test, was used. One-way ANOVAs with Tukey's multiple comparison tests were used to analyze the equality of the five treatment replicates pre-experimentation (July 2010), based on *Typha* percent cover and stem counts. A one-way ANOVA with Tukey's multiple comparisons was used to test for differences in sediment depth among all five treatment replicates. The Kruskal-Wallis non-parametric alternative to ANOVA was used to test for differences among the five treatment replicates based on average soil moisture for both sampling years (2010, 2011). One-way ANOVAs with Tukey's multiple comparisons were used to test for differences among mean bulk density samples and for mean percent organic matter samples among the five treatment replicates.

RESULTS

Typha

While the layout of the five treatment replicates for this study was based on visual estimation of *Typha* percent cover equality, treatment replicate 3 had statistically more stem counts (Table 2) than the other four replicates in July 2010 ($F=7.98$, $df=4$, $p = 0.000$). Treatment replicates 1, 2, 4, and 5 had statistically similar amounts of stem counts. For *Typha* percent cover, there was a little more variability (Figure 4); pre-treatment 2010 replicate 3 had significantly greater *Typha* percent cover than replicates 1, 2, and 4 but was similar to replicate 5 ($F=8.16$, $df=4$, $p=0.000$). *Typha* cover of replicates 1, 2, 4, and 5 were statistically similar.

The total number of *Typha* x *glauca* stems sampled across all treatments and replicates was 8,530 (~70% of all *Typha* sampled) whereas the total number of *Typha angustifolia* stems sampled was 4,015 (~30%). The largest number of *Typha angustifolia* stems (1,308, 35%) was recorded in treatment replicate 4, which was positioned closest to Kents Creek. *Typha angustifolia* was mixed together with the more dominant *Typha* x *glauca* in the remaining four treatment replicates in a random fashion.

I will first report the success of each treatment combination based on the ability of each combination (e.g., C1S1T) to reduce *Typha* stem counts over the two-year period of the study (pre-treatment 2010 vs. post-treatment 2011 sampling). Six treatment combinations significantly reduced the number of *Typha* stems: C1W1, C1SW1, C1WT, C12SW1, C12W1T, and C12SW1T (Table 3). The C12W1T treatment significantly reduced *Typha* stem counts the most (15.9), while treatments C12SW1T (12.9) and C12SW1 (12.2) also reduced large numbers of *Typha* stems. The control treatment plots gained an average of 13 *Typha* stems throughout the two years of the study, the greatest increases observed in the study. Four of the six treatments that significantly reduced *Typha* stem counts also significantly reduced *Typha* percent cover: C1SW1, C12SW1, C12W1T, and C12SW1T (Table 4). The other two treatments that significantly reduced *Typha* cover were C12 and C12W1. Treatment C12SW1 decreased *Typha* cover by an average of ~25%, the largest significant reduction. Treatments C12W1, C12W1T, and C12SW1T all reduced *Typha* cover by more than 20%. Treatment C12S reduced *Typha* cover an average of ~28%, but was not significant. Treatment combinations that were significant in reducing both *Typha* stems and percent cover through both years of the study have the wick treatment (W) in common; this was applied in late summer.

In control plots, mean *Typha* cover increased by 28%, while mean *Typha* stem counts increased by 13 stems. Control plots showed major increases in *Typha* stem counts from fall of 2010 to spring 2011, as opposed to during the growing season (Figure 5).

All treatment plots, with the exception of C1, C1S, C1T, and C1ST (all with cutting in year 1 only) reduced *Typha* stems and percent cover (Tables 3, 4). Plots with only cutting in year 1 (C1) showed increases in *Typha* from August 2010 to June 2011 (e.g., C1S treatment) (Figure 6). Initial reductions of *Typha* stems occurred, but lack of treatments in the following year allowed re-expansion of *Typha*.

The success of the treatments, based on *Typha* percent cover and stem count, varied among treatment replicates (Table 2). Treatment replicates 1 and 3 had significantly lower mean *Typha* stem counts at the end of the study (August 2011) compared to the beginning (July 2010). Treatment replicate 3 reduced the largest average amount of both *Typha* stem counts (-14.8) and percent cover (-14.2), while replicate 1 was reduced an average of 5.5 stems across the whole replicate.

Sedge/grass Meadow

Carex lacustris and *Calamagrostis canadensis* were two of the primary sedge/grass meadow species present in the five treatment replicates at Kents Creek. *Calamagrostis canadensis* was randomly distributed in the study area and did not occur in every replicate (Table 5). *Calamagrostis canadensis* did not increase significantly in percent cover in any of the treatment combinations through both years of the study. Individual treatment plots did show increases in *C. canadensis*, but there were no observable patterns leading to this increase. Overall, plots that had treatments applied and had *C. canadensis* present before treatment in 2010 increased the percent cover of *C. canadensis* by 12%. Control plots had an increase of just 6% in the cover of *C. canadensis*. From July 2010 to August 2011, treatment replicates 1 and 4 increased an average of ~12 % in *C. canadensis* cover; while none of the other replicates had substantial increases in cover. *Carex lacustris* was more prevalent at the study site, and every treatment replicate averaged at least 1% cover at the beginning of the study (Table 5). Based on individual treatment combinations, C. *lacustris* showed significant increases for multiple combinations. Eight treatments significantly increased the amount of *C. lacustris,* including C1, C1W1, C1SW1, C1WT, C1SW1T, C12W1, C12SW1, and C12W1T (Table 6). Treatment C1 added 26% *C. lacustris* cover, more than any other treatment (Table 6).   Coincidentally, five treatments that significantly reduced *Typha* stems and four treatments that significantly reduced *Typha* percent cover significantly increased *C. lacustris* cover. Overall, *C. lacustris* increased an average of 18% for all treatment plots. Control plots also increased *C. lacustris* percent cover by 13%. Treatment replicates 1, 2, and 3 increased percent cover of *C. lacustris* by at least 14% for all plots (treatment and control) from July 2010 to August 2011.   Treatment replicate 3 had the largest increase in percent cover, increasing *C. lacustris* by ~21%.

Water Levels

In 2010, water levels peaked in July, and the lowest growing season water levels occurred in late August. For 2011, water levels were characterized by mean, minimum, and maximum levels for each treatment replicate (Table 7). Data from water-table wells closely follow Lake Ontario gauged water-level data from the National Oceanic and Atmospheric Administration (NOAA 2011). The second field season (2011) better represents the annual fluctuation—higher water levels in spring and summer and drawdown in fall (Figure 7).

Soil Moisture

For both years of the study, there were significant differences in the mean soil moisture among the five treatment replicates (Kruskal-Wallis, 2010: $H=29.25$, $df=4$, $p=0.000$, 2011: $H=16.3$, $df=4$, $p=0.003$). Since there is no multiple comparisons test for nonparametric statistics, the Kruskal-Wallis test does not identify which treatment replicates are significantly different. However, further analysis of the 2011 data shows that the median of treatment replicate 3 is 90.55% soil moisture and the other treatment replicates are as follows: replicate 1, 96.55%; replicate 2, 100%; replicate 4, 99.95%; and replicate 5, 100%, suggesting that replicate 3 may be drier than the rest (Table 9).

In 2010, the difference was more obvious; treatment replicate 3 had a median of 72.25% and all other replicates had medians greater than 90% (Table 8). The average soil moisture for both years, throughout the sampling year, provides more information on the difference in soil moisture between treatment replicate 3 and the other four replicates (Table 10).

The second field season (2011) was substantially wetter than the first (2010); the whole month of June (2011) had 100% soil moisture (standing water). From 2010 to 2011, soil moisture increased 3.2% for replicate 1, 0.6% for replicate 2, 22.7% for replicate 3, 1.3% for replicate 4, and 0% for replicate 5. Replicate 5 had a mean of 99.5% soil moisture for both years, the wettest of the five replicates. In both years, treatment replicate 3's mean soil moisture was less than the other four replicates beginning in late July, and generally decreasing through August (Figures 8, 9). Treatment replicate 1 showed a subtle difference from treatment replicates 2, 4, and 5 by having slightly lower average soil moisture.

Sediment Depth

Sediment depth to clay differed significantly (ANOVA: F=170.12, df=4, p=0.000). Among the five treatment replicates, replicates 1 and 3 had significantly shallower soil depths. Replicates 1 and 3 had statistically similar sediment depth but were significantly different from the other three replicates. Treatment replicates 2, 4, and 5 had significantly greater soil depths than replicates 1 and 3 and were significantly different from each other (Figure 10).

Soils

Differences in the mean soil bulk density among the five treatment replicates were significant (ANOVA , F=18.96, df=4, p=0.003). Tukey's multiple comparisons test showed that treatment replicate 3 differed from the other four treatment replicates based on soil bulk density. Treatment replicate 3 bulk density was significantly higher, with a mean of 0.384g/cm^3, compared to treatment 1 (0.239g/cm^3), treatment 2 (0.153g/cm^3), treatment 4 (0.208), and treatment 5 (0.115). For the five treatment replicates, differences among means for percent organic matter were not significant (ANOVA: $F=4.71$, $df=4$, $p=0.06$). However, there were observable differences among the means. Treatment replicate 3 had the lowest percentage of organic matter with 20.8% organics, while replicate 1 contained 23.8%, replicate 2 contained 59.7%, replicate 4 contained 23.4% and replicate 5 contained 43.7 % organic matter.

DISCUSSION

Cattails are resilient plants that, with the right environmental conditions, can be invasive and difficult to control. Based on my study in a drowned river mouth wetland in Lake Ontario, the success of controlling *Typha*, the majority of which was the hybrid *Typha* x *glauca*, varies depending on the combination of treatments applied and the time of year when treatments were made. The most successful treatments through both years of the study contained the cut treatment (C) in years 1 and 2, the spray (S) or till (T) treatment, and the wick treatment (W) in late summer of the first year. This combination of treatments eliminated approximately half of the pre-existing *Typha* plants (by up to 15 stems/m^2) and reduced percent cover of *Typha* by an average of 67%. The wick treatment applied in late summer seemed to be the most important treatment in the combination, as it was included in every treatment combination that significantly reduced *Typha* stems. More importantly, the wick treatment combined with cutting only in the first year also reduced *Typha* stems significantly. This was the only treatment that significantly reduced *Typha* stems without other secondary treatments (e.g., spraying or tilling). The wick treatment was done by applying glyphosate (Rodeo) to re-sprouting *Typha* in late summer, allowing herbicide to be absorbed by the plant and eventually into rhizomes**.** Other studies have shown the importance of applying herbicides later in the year to control *Typha* effectively (Beule 1979, Messersmith et al. 1992). A similar invasive species, *Phragmites australis*, has a life cycle analogous to *Typha* (rhizomatous storage) and is best controlled by herbicide when sprayed at the end of the growing season (Carlson et al. 2009).

Other treatments combined with the wick treatment increased stress on cattails and led to improved success at reducing *Typha* growth, as had been found elsewhere (Thayer and Ramey 1986). Treatments with cutting in year 1 (only) combined with the wick treatment (and/or till and spray) did significantly reduce *Typha* stems, but only half as much as the treatments with cutting in both years and wicking. Cutting treatments applied in late June/early July of each year of the study, when carbohydrate reserves are at their lowest, increased stress on the plant and increased the likelihood of killing the plant in the future. Sojda and Solberg (1993) stated that cutting, crushing, and disking were most effective when conducted during a three-week window from one week before to one week after the pistillate spike is lime green and the staminate spike is dark green.

Three of the six treatment combinations that significantly reduced *Typha* stem counts contained the till or spray treatment, independent of each other (C1**S**W1,

C12**S**W1, C1W**T** C12W1**T**, C12**S**W1**T**) (Table 3). The tilling treatment, combined with the other treatments, had variable success at reducing *Typha* stems. Three of the till treatments trended toward increasing *Typha* stems during the study, even though the increases were not significant ($p > 0.05$). The treatment combination C1T increased an average of 9 *Typha* stems during the study, only slightly less than the increased stem number in control plots (13). However, the treatment C12W1T significantly reduced a mean of 16 *Typha* stems. The till treatment improved *Typha* reduction only in combination with the wick treatment; otherwise, the till treatment was rather unsuccessful. However, alternative till treatment methods have proven to be effective, Apfelbaum (1985) found that crushing (*Typha* rhizomes) was most effective when conducted multiple times after June and when standing water occurred in study plots after treatment. Since we could not control the water levels in Lake Ontario, this treatment method was not feasible. The variable success using the till treatment was likely caused by manually chopping *Typha* rhizomes with a shovel and multiple people applying the treatment (people may have done it differently). Since we were chopping the rhizomes by feeling for them with the shovel, there is some variability on how well each and every rhizome was chopped/disconnected.

The same type of variable results existed with the spray treatment; three spray treatment combinations reduced *Typha* stems significantly, while five treatments were not significant. All of the significant treatment combinations that included spraying also included the wick treatment. The C1S treatment, which was independent of other treatments except for cutting in year 1, was not significant at reducing *Typha* stems; therefore, this treatment alone is not likely to reduce *Typha* stem counts effectively. Two of the treatment combinations that included the spray treatment resulted in slightly increased *Typha* stem counts, but these were not significant. The spray treatment was conducted by applying glyphosate (Rodeo) to previously cut *Typha* stalks during the initial sampling in late June/early July. The problem with this technique is that, during early/mid- summer, *Typha* is not re-establishing carbohydrate reserves in the rhizomes, so herbicide does not appear to affect the root system. Beule (1979) reported that herbicides were most successful when applied later in the year, after pollination and staminate tops were lost. Personal observation of *Typha* stems immediately after the spray treatment revealed no signs of biological stress, as plants grew 10-15 cm in 2-3 days. Later in the growing season noticeable stress on the plant was documented (stunted), but the plants usually did not die.

As expected, if treatments were successful at reducing *Typha* stems, they were likely to be successful at reducing *Typha* cover. Four of the six treatment combinations that reduced *Typha* stems also were significant at reducing *Typha* cover. Five out of the six treatments that were significant for reducing *Typha* cover contained the wick treatment; the outlier was the C12 treatment, which was significant also (Table 4). The inclusion of more treatments in addition to the wick treatment increased the amount of *Typha* cover reduced (Table 4). This is likely an effect of the increased amount of stress put on *Typha* throughout both years of this study (Thayer and Ramey 1986). Furthermore, percent cover may not adequately describe success at controlling *Typha*. Personal observations revealed sprouts of

Typha that were stressed by initial treatment but not killed. In August, when follow-up sampling took place, short thin *Typha* sprouts were still alive. So, even though the data may show large decreases in percent cover, it is likely that those stressed plants lived and re-emerged the following year.

Environmental Variables and *Typha* Control

Environmental variables did not differ substantially among treatment combinations in a given treatment replicate. However, environmental conditions did vary among the five treatment replicates. All five treatment replicates had the same 16 (except for minor differences in replicates 4 and 5) randomly assigned treatments. While I may not be able to assess the effects environmental variables had on the individual treatments, I can analyze how the environmental variables affected the mean *Typha* reduction at the replicate level. While this may not pinpoint the effects environmental variables had on each treatment technique (e.g., cut, till, spray), it can give insight on broader techniques for controlling *Typha*. Percent soil moisture, an important variable when considering altered water levels in Lake Ontario (Wilcox et al. 2008), had a significant effect on success of treatments among the five replicates. Treatment replicates 1 and 3 were the only replicates to reduce *Typha* stems significantly replicate-wide (Table 2). These two treatment replicates had the two lowest soil moistures among the five (Table 10). Treatment replicate 3 had a soil moisture range twice as large as any other replicate in 2010 and 6% more than any other replicate in 2011. Differences in soil moisture among the five treatment replicates were likely tied to the elevation of each replicate (Table 11). Treatment replicates with lower moistures occurred at slightly higher elevations, where environmental variables were not fully influenced by high lake levels. Subsequently, *Typha* appeared more vulnerable to control, as lower soil moisture led to more success at controlling *Typha* at the replicate level.

Other studies have documented the importance of increased soil moisture for expansion of *Typha* because the large, fleshy rhizomes of *Typha* are less tolerant of low soil moisture (Weaver and Himmel 1930, Linde et al. 1976, van der Valk and Davis 1980, Wilcox et al. 2008). In terms of water chemistry, increased soil moisture and prolonged inundation periods caused by altered water levels can release phosphorus (P) through internal eutrophication from wetland soils; *Typha* x *glauca* is known to take advantage of P and use it to increase its growth rate (Boers and Zedler 2008). This likely explains how *Typha* x *glauca* can invade and dominate new areas at the expense of other wetland species. Boers and Zedler (2008) did not find any areas dominated by *Typha* x *glauca* where water levels fluctuated. This may explain why *Typha* has not fully dominated areas like replicate 3 and is easier to control where soils experience more fluctuation from wet to dry**.** If a more natural hydrologic cycle is implemented for Lake Ontario and treatments are applied to *Typha*-dominated wetlands hydrologically connected to the lake, success at reducing *Typha* will likely increase.

The bulk density analysis showed a similar pattern regarding the significant difference of treatment replicate 3 as compared to the other replicates, and the effectiveness replicate 3 had at controlling *Typha*. Soil bulk density is a measure of the ratio of the mass of the mineral grains to the total volume (Dadey et al. 1992). In this study, this meant that treatment replicate 3 had the highest ratio of mineral matter among the five replicates. This may be evidence that *Typha* has recently invaded replicate 3 and this area has not had time to accumulate litter and increase soil organic matter, in turn decreasing the bulk density of the soil. Higher bulk densities suggest that there is less pore space available in the soil, which reduces the amount of water the soil can hold (Adams and Froehlich 1981). This could be a contributor to the lower soil moisture found in replicate 3, and a reason this replicate was significant at reducing *Typha*. While replicate 1 soil bulk density was not significantly different than replicates 2, 4, and 5, it did have the second highest bulk density among the five replicates. This is more evidence for the relationship between bulk density/pore space and successful *Typha* control.

The trend in bulk density of the soils among the five treatment replicates was confirmed by the measure of percent organic matter for each replicate. Although not significant, treatment replicate 3 had the lowest average percent organic content (~20%); this provides further evidence that the *Typha* in replicate 3 may have invaded that area more recently. Because the time since invasion probably was less, it is possible that the soil has not had time to transition into a more organic-based substrate. In addition, replicate 3 had lower soil moisture (higher elevation) compared to other replicates; drier areas undergo faster decomposition rates that prevent build up of organic matter. *Typha* invasion has been associated with increased litter biomass and soil organic matter; furthermore, a recent study showed that new, isolated patches of *Typha* occurred at sites that did not differ in nutrient status from uninvaded controls (Tuchman et al. 2009), supporting the theory that replicate 3 has been recently invaded. Treatment replicate 1 was similar to replicate 3, with 23.8% soil organic matter, further confirming the relationship between bulk density and organic matter. Treatment replicates 2 and 5 had substantially higher percentages of organic matter, likely caused by domination of *Typha* and production of litter over a longer period of time, as compared to replicate 3. Tuchman et al. (2009) found that *Typha* invasion was linked to increased soil organic matter and litter biomass. In this study, sediment depth was determined by inserting a soil auger into the ground until it reached clay and would not go any further. Treatment replicates 1 and 3 had significantly thinner organic sediment than the other three replicates, further supporting my analysis of the relationship among the five treatment replicates, their soil composition, and time since *Typha* expansion.

Based on the results of this study, sediment depth, percent organic matter, bulk density, soil moisture, and the ability of treatment replicates to control *Typha* significantly are all dependent on one major factor at Kents Creek—lake levels. Lake Ontario water levels have been managed since about 1960 largely to accommodate shipping, hydroelectric power, and riparian property owners, while the environment (hydrology, vegetation) was not an interest. Fifty years later, a regulated lake level has changed wetland plant communities that are hydrologically connected to Lake Ontario. Wilcox et al. (2008) documented a two-fold increase in percent cover of *Typha* and 40% decline in percent cover of meadow marsh at Kents Creek from 1960 (before managed lake levels) to 2001. In this study, areas at slightly lower elevations (treatment replicates 2, 4, 5, and possibly 1) experienced comparatively higher soil moistures that allowed for expansion of *Typha*. *Typha*, a highly invasive plant that favors moist, stable hydroperiods, took over those suitable habitats, in turn altering the composition of the soil. In addition, at the treatment replicate level, *Typha* stands were much harder to control in areas that had greater than ~ 95% soil moisture. Treatment replicate 3 had a mean soil moisture lower than 92% in both years (75% in 2010) and was most successful at significantly reducing *Typha*. A study using controlled hydrologic treatments showed that *Typha latifolia* must experience soil moisture less than 5% to cause complete root mortality (Asamoah and Bork 2010). Soil composition seemed to be less affected by *Typha* invasion in treatment replicate 3; this replicate was elevated (Table 11) in comparison to the others, and it appeared that *Typha* did not have time to alter soil properties.

Characteristics of *Typha* expansion were observed from the vegetative composition in treatment replicate 3. Replicate 3 had the highest percent cover of *Typha* at the beginning of the study (Figure 4). This could possibly be attributed to the recent expansion of *Typha* into the area of treatment replicate 3. With less *Typha* litter accumulation in previous years, the ground was less devoid of sunlight; therefore, more individual *Typha* plants were likely to grow. As expansion continued and *Typha* litter built up, fewer individual plants were able grow (as observed in replicates 2 and 4). There appeared to be a peak in stem density of *Typha* during colonization; when *Typha* fully dominates an area, it produces so much litter that it impedes its own ability to produce more plants. Vaccaro et al. (2009) showed that species density was negatively correlated to *Typha* litter biomass but was not related to aboveground live *Typha* biomass. Recent expansion of *Typha* may lead to high cover of live *Typha*, but it does not negatively affect other understory species until the stand has time to produce copious amounts of litter (Vaccaro et al. 2009), although this threshold is only reached if hydrological conditions allow it. The increased, stable water levels that occur in Lake Ontario appear to allow this threshold to be reached at higher and higher elevations.

There is a chance that lake levels will never be regulated to accommodate wetland ecological communities. Without periodic low lake levels, *Typha* will never be kept in check by lower soil moisture, and sedge/grass meadow species will continue to suffer. *Typha* expansion will likely occur as far upslope as the level of the lake allows, leading to the disappearance of any remaining sedge/grass meadow communities. If a more environmentally friendly hydrologic cycle is not implemented, methods tested in this study still may be able to reduce *Typha* on Lake Ontario if applied on a multi-year basis. Above average regulated lake levels occurred in 2011 that likely made treatment efforts more difficult (Figure 1). With a combination of treatments, most importantly cutting and wicking (in late summer), treatment of *Typha* is still a feasible option to reduce its overall cover and allow for expansion of sedge/grass meadow.

Sedge/grass Meadow Restoration

Calamagrostis canadensis and *Carex* species have been displaced by *Typha* in many lake-connected wetlands across Lake Ontario (Wilcox et al. 2008). The robust morphology and the abundant litter production by *Typha* allows it to shade out smaller, less competitive (sedge/meadow) species such that ultimately decline in response (van der Valk 1986, Brazner et al. 2007, Freyman 2008, Farrer and Goldberg 2009, Vaccaro et al. 2009). Successful techniques at controlling *Typha* will likely lead to increases in percent cover of sedge/grass meadow species with time if the species existed before *Typha* invasion or were present on site. *Carex lacustris* and *C. canadensis* were the two primary sedge/grass meadow species sampled in the five treatment replicates. *Carex stricta*, another primary component of the sedge/grass meadow community, was not present in any of the five treatment replicates but was observed at slightly higher elevations.

Calamagrostis canadensis did not show any significant increases for individual treatment combinations, probably due to the small number of treatment plots that contained *C. canadensis. Calamagrostis canadensis* was present in random patches throughout the study area (Table 5); in addition, the random placement of treatment combinations resulted in the presence of *C. canadensis* in different treatment combinations among the five treatment replicates. This made the evaluation of *C. canadensis* cover based on each individual treatment combination difficult. A better way to analyze *C. canadensis* was to look at treatment plots that contained *C. canadensis* before treatment and how the percent cover in those plots increased throughout the study. The treatment plots that contained *C. canadensis* before treatment in the spring 2010 increased an average of 12 % cover over the two years of the study, independent of which treatment combination was used. The pre-study cutting and removal of live and dead material before vegetation sampling and treatment was likely the first step in re-establishing *C. canadensis*. The removal of live and dead *Typha* stems, which were nearly 100% of the vegetative cover, opened the canopy initially, allowing the growth of graminoid species (Hall and Zedler 2010). In addition, the treatments increased light availability and reduced competition, likely allowing *C. canadensis* to grow. Mean percent cover of *C. canadensis* in control plots increased half as much as in treatment plots (~6% cover compared to 12% in treatment plots). The increase in *C. canadensis* cover in the control plots was likely caused by the initial cutting in May 2010 to remove the *Typha* litter and the disturbance around each control plot during the study. Both of these actions resulted in decreasing the total cover of the treatment replicates, either by removing dead *Typha* litter or by treating adjacent plots that resulted in opening invasion windows where sedge/grass meadow species were able to compete.

Carex lacustris was more prevalent in the five treatment replicates than *C. canadensis*. This is likely because the majority of the replicates (replicates 1, 3, 4, and 5) were close to the water's edge (~10m). In a *Carex* revegetation study (Yetka and Galatowitsch 1999), *C. lacustris* had the highest rates of survival at or near the water's edge. Overall, increases in *C. lacustris* cover among the five treatment replicates ranged from 6% to 20% (Table 5). Reduction in *Typha* stems/percent cover can directly influence the response of graminoid species (Hall and Zedler 2010). Treatment replicates 1 and 3 had two of the three greatest increases in *C. lacustris* percent cover. Not surprisingly, they were the only two replicates in which *Typha* stems were significantly reduced across all treatments. Reducing the amount of *Typha* increases light availability and reduces competition, both of which favor growth and expansion of *C. lacustris*. Hall and Zedler (2010) showed that native graminoids responded to *Typha* harvest by increasing cover by 230 and 170% in experimental plots that had *Typha* cut and removed at least twice a year. Treatment replicates 1 and 3 had the two lowest average soil moistures among the five replicates. Decreased soil moisture (lower water periods) increases cover of sedge/grass meadow species, (Quinlan and Mulamoottil 1987, Wilcox et al. (2008). This is evidence that *C. lacustris* could increase its cover in wetlands hydrologically connected to Lake Ontario if water levels were altered to mimic more natural variation and treatment techniques proven effective in this study were applied.

Carex lacustris percent cover was analyzed for every treatment plot that had at least 1% *C. lacustris* cover at the beginning of the study. Any plot that had a treatment applied increased the pre-existing *C. lacustris* cover by an average of 18%, while *C. lacustris* cover increased in control plots by an average of 13%. As with *C. canadensis*, the initial cutting in May 2010 and the disturbance from adjacent treatments likely led to increases in percent cover of *C. lacustris* in control plots. Treatments C1, C12W1T, and C12W1 increased *C. lacustris* cover by at least 20% (Table 3). The large increase in percent cover by the C1 treatment is an outlier compared to the other treatment combinations that were successful at *Typha* control and *C. lacustris* re-vegetation. The cutting treatment in early July 2010 initially eliminated all *Typha* cover in C1 treatment plots, giving *C. lacustris* plants a competitive advantage for absorbing sunlight. *Carex lacustris* is close to its maximum size/cover in early July; therefore, increased photosynthesis from abundant sunlight could have led to expansion of *C. lacustris* in subsequent years. Although the response was slow, graminoid vegetation expanded 1 m in 4 × 8 m plots by the end of a two-year *Typha* manipulation study (Hall and Zedler 2010). Surprisingly, *C. lacustris* continued to expand through the second year of the study even though there were no treatments following cutting in year 1. The success of treatments C12W1T and C12W1 was more expected since both of these treatments were proficient at reducing *Typha* percent cover. Reduced competition from *Typha* due to intensive, successful control techniques likely allowed *C. lacustris* to grow and expand in treatment plots. My study showed that if control techniques are implemented on *Typha* in areas where remnant sedge/grass meadow species exist, *Typha* control will likely lead to increases in cover of sedges and grasses.

Preliminary Treatment Recommendations

Based on the findings of my study, the most effective treatment for *Typha* control in Lake Ontario wetlands is cutting and tilling *Typha* in late June, and then applying the wick treatment in August; this should be implemented for two consecutive years. This combination of treatments reduced *Typha* stem counts the most over two-years at Kents Creek. The spray treatment had variable results; therefore, I would not recommend this treatment even if resources are available. If time and resources are limited, I would recommend implementing cutting and wicking, as these two treatments were the most effective at reducing *Typha* stems. Data will be collected in August 2012 at Kents Creek to assess treatment effects through three years. Further recommendations can be made once those data are analyzed.

Treatments performed on small scales (< 2 ha), like in this study, are feasible with a small group of workers. Cutting with a steel blade trimmer is labor intensive but the most effective way to cut *Typha* without heavy machinery. Wicking *Typha* with glyphosate (Rodeo) could be done by hand, if native vegetation persists, or herbicide could be applied aerially with backpack sprayers to dense *Typha* stands. Tilling rhizomes is very labor intensive but can be done manually with a roto-tiller. I would not recommend applying the till treatment unless it can be done with larger machinery. A small group of workers could apply treatments to areas < 2 ha in approximately one week. For stands > 2 ha, I would recommend use of equipment that is more time and labor efficient at applying the treatments. The Marshmaster©, a tracked amphibious vehicle that can be equipped with a brush hog, can mow *Typha* in places a tractor cannot go. Boats built to shred aquatic vegetation in marinas can be used to cut up *Typha* also. Tilling can be performed using tractors/Marshmaster© equipped with a disk. The fangueo technique, tractors equipped with metal-blade like tires, is used as a successful way to till up *Typha* and increase habitat heterogeneity (and plant diversity) in Costa Rican wetlands (Osland et al. 2011). For large monocultures of *Typha*, the Marshmaster© can be equipped with spraying equipment to apply herbicide to large areas quickly. Other options include use of airplanes or helicopters to apply herbicide to large monocultures of invasive species. For agencies with budgetary concerns, herbicide can effectively be sprayed from an Argo©, a smaller amphibious tracked vehicle. Larger equipment, such as the Marshmaster© or an Argo© can apply herbicide to areas 4-10 ha/day. For areas that contain native graminoid vegetation mixed with *Typha*, more labor intensive herbicide application techniques (hand wicking) should be applied if managers fear overspray will harm the existing graminoid vegetation.

Herbicides with surfactant were once commonly used to control invasive species; surfactants can be harmful to amphibians and reptiles. For managers fearing negative effects of herbicide on amphibian and reptile populations, current glyphosate (Rodeo) is wetland approved and surfactant free.

If lake levels are at all predictable under the current or new regulation plan, applying a two-year treatment program should be performed during lower than average summer water levels, as lower water levels decrease soil moisture and lead to increased *Typha* reduction when treatments are applied.

C = cut	C1	C1S	C1T	C1ST
S = spray	C12	C12S	C12T	C12ST
W = wick	C1W1	C1SW1	C1W1T	C1SW1T
T = till (year 1)	C12W1	C12SW1	C12W1T	C12SW1T
1, 2 = years	C1W12	C1SW12	C1W12T	C1SW12T
	C12W12	C12SW12	C12W12T	C12SW12T

Table 1. Treatment combinations devised for the two-year *Typha* control and sedge/grass meadow restoration study at Kents Creek (2010 and 2011).

	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Replicate 5
2010 Stems before treatment	26.8	24.4	34.6	25.8	27.0
2011 Stems after treatment	21.3	24.3	19.8	23.1	24.1
Stems reduced	5.5	0.1	14.8	2.7	2.9
P-value (paired t-test)	0.000*	0.966	0.000	0.274	0.216
2010 Percent cover before treatment	35.2	31.7	41.9	29.5	35.9
2011 Percent cover after treatment	24	29.7	27.7	24.6	34.2
Percent cover reduced	11.2	2.0	14.2	4.9	1.7

Table 2. Mean *Typha* stem counts, percent cover, and the amount of each reduced per replicate (pre-treatment in 2010 to post-treatment in 2011). P-values show the significant differences in *Typha* stems from the beginning of the study to the end. Replicate 3 paired t-test: n=24, T-value=5.19, p=0.000; replicate 1 Wilcoxon signed-ranks test*: n=24, Wilcoxon statistic=300.0, p=0.000.

Treatment	P-value	Stems added/reduced
C1	0.368	5.8
C1S	0.822	1.5
C1T	0.041**	9.2
C1ST	0.590	1.7
C12	0.391	-3.3
C12S	0.475	-8.4
C12T	0.776	2.2
C12ST	0.587	-5.3
C1W1	0.048*	-6.1
C1SW1	0.013*	-8.2
C1WT	0.018*	-8
C1SW1T	0.181	-4.2
C12W1	0.059	-6.4
C12SW1	0.020*	-12.2
C12W1T	0.005*	-15.9
C12SW1T	0.002*	-12.9
control	0.000**	13.4

Table 3. Treatment significance based on paired t-tests run on *Typha* stem counts for pre-treatment 2010 vs. post-treatment 2011 samples. *Treatments with p-values less than 0.05 significantly reduced *Typha* stem counts. ** denote treatments that had significantly more *Typha* stem counts at the end of the study. Both control plots from all five treatment replicates were averaged together. Paired t-test statistics: C1W1, n=10, T-value=2.29; C1SW1, n=8, T-value=3.33; C1WT, n=10, T-value=3.33; C12SW1, n=10, T-value=2.81; C12W1T, n=7, T-value=4.34; C12SW1T, n=8, T-value=5.03.

Treatment	P-value	Percent cover added/reduced
C1	0.234	12.4
C1S	0.433	7.4
C1T	0.278	10.7
C1ST	0.211	15.6
C12	0.049*	-14.2
C12S	0.136	-27.9
C12T	0.886	-2.9
C12ST	0.172	-18.9
C1W1	0.707	-2.1
C1SW1	0.040*	-6.5
C1WT	0.246	-4.4
C1SW1T	0.494	-5.3
C12W1	0.001*	-21
C12SW1	0.000*	-25.5
C12W1T	0.002*	-21.8
C12SW1T	0.014*	-23.2
Control	0.000**	28

Table 4. Treatment significance based on paired t-tests run between *Typha* percent cover of pre-treatment 2010 vs. post-treatment 2011 samples. A Wilcoxon signed-ranks test was used for treatment C12SW1T. * Treatments with p-values less than 0.05 significantly reduced *Typha* percent cover. ** Treatments had significantly more *Typha* cover at the end of the study. Both control plots from all five treatment replicates were averaged together. Statistics: C12, n=4, T-value=3.22; C1SW1, n=8, T-value=2.51; C12W1, n=9, T-value=5.20; C12SW1, n=10, T-value=9.14; C12W1T, n=7, T-value=5.20; C12SW1T, Wilcoxon signed-ranks test, n=8, Wilcoxon statistic=36.0.

Average *Calamagrostis canadensis* percent cover			
treatment replicate	pre-treatment 2010	post-treatment 2011	percent added/decreased
1	5.8	17.8	12
2	0	0	0
3	1.7	1.2	-0.5
4	12.2	25	12.8
5	0	0	0
Average *Carex lacustris* percent cover			
treatment replicate	pre-treatment 2010	post-treatment 2011	percent added/decreased
1	7	21	14
2	3.7	19.5	15.8
3	4.7	25.2	20.5
4	1.1	7.9	6.8
5	3.3	11	7.7

Table 5. Mean percent cover of *Calamagrostis canadesis* and *Carex lacustris* pre-treatment 2010 and post-treatment 2011 among the five treatment replicates.

	Mean Percent Cover			
Treatment	pre-treatment 2010	post-treatment 2011	percent cover added	p-value
C1	4.20	30.00	25.80	0.035*
C1S	1.00	3.60	2.60	0.34
C1T	6.20	21.75	15.55	0.226
C1ST	2.60	8.75	6.15	0.192
C12	3.20	25.00	21.80	0.081
C12S	4.00	20.00	16.00	0.116
C12T	3.40	20.00	16.60	0.262
C12ST	2.40	12.00	9.60	0.274
C1W1	3.67	18.00	14.33	0.027*
C1SW1	7.71	16.43	8.71	0.006*
C1WT	4.00	21.67	17.67	0.006*
C1SW1T	7.88	26.38	18.50	0.022*
C12W1	5.43	25.86	20.43	0.036*
C12SW1	4.33	16.44	12.11	0.045*
C12W1T	2.71	24.29	21.57	0.007*
C12SW1T	2.88	14.50	11.63	0.106
Control	3.30	12.80	9.50	0.016*

Table 6. Mean percent cover of *Carex lacustris* before treatment in 2010 and after treatment in 2011 with the amount of cover added and the p-values based on paired t-tests. * Treatments had significantly more cover post-treatment 2011. The two control plots from all five treatment replicates were averaged together. Paired statistics: C1, n=4, T-value=-3.66; C1W1, n=9, T-value=-2.69; C1SW1, n=7, T-value=-4.10; C1WT, n=9, T-value=-3.73; C1SW1T, n=9, T-value=-2.94; C12W1, Wilcoxon signed ranks test, n=7, Wilcoxon statistic=21.0; C12SW1, n=9, T-value=-2.37; C12W1T, n=7, T-value=-4.01.

2011 ground-water elevation	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Replicate 5
Mean	74.914	74.93	75.082	74.93	74.951
Max	75.186	75.156	75.233	75.203	75.176
Min	74.74	74.74	74.946	74.785	74.67

Table 7. The mean, maximum, and minimum ground-water elevation for five treatment replicates at Kents Creek in 2011 (meters IGLD1985).

Kruskal-Wallis Test on soil moisture 2010

replicate	N	Median	Ave Rank	Z
1	8	92.90	12.9	- 2.06
2	8	99.20	29.3	2.37
3	8	72.25	5.4	- 4.09
4	8	97.35	23.1	0.71
5	8	99.60	31.9	3.08
Overall			40	20.5

H = 29.25 DF = 4 P = 0.000
H = 29.37 DF = 4 P = 0.000 (adjusted for ties)

Table 8. The outcome of a Kruskal-Wallis test showing differences based on median soil moisture among the five replicates at Kents Creek in 2010.

Kruskal-Wallis Test on soil moisture 2011

replicate	N	Median	Ave Rank	Z
1	12	96.55	25.8	-1.03
2	12	100.00	39.9	2.08
3	12	90.55	15.2	-3.40
4	12	99.95	33.3	0.61
5	12	100.00	38.4	1.75
Overall			60	30.5

H = 16.30 DF = 4 P = 0.003
H = 18.63 DF = 4 P = 0.001 (adjusted for ties)

Table 9. The outcome of a Kruskal-Wallis test showing differences based on median soil moisture among the five replicates at Kents Creek in 2011.

Percent soil moisture					
	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Replicate 5
7/10/2010	91.9	97.2	76.0	97.2	99.6
7/15/2010	92.8	98.6	71.5	95.6	98.5
7/23/2010	96.6	100	94.8	99.8	100
7/29/2010	98.8	100	90.9	100	100
8/6/2010	94	98.9	73	96.8	100
8/13/2010	93	98.9	70.2	97.2	99.1
8/21/2010	91.7	99.7	58.8	97.5	99.3
9/7/2010	86.6	99.5	65.6	98.5	99.6
Mean	**93.2**	**99.1**	**75.1**	**97.8**	**99.5**
Max	98.8	100	94.8	100	100
Min	86.6	98.6	58.8	95.6	98.5
Range	12.2	1.4	36	4.4	1.5
4/8/2011	100.0	100.0	100.0	100.0	100.0
4/22/2011	98.3	100.0	99.1	100.0	100.0
5/5/2011	100	100	99.2	100	100
5/20/2011	100	100	100	100	100
7/22/2011	100	100	87.2	100	100
7/29/2011	94.8	100	92.9	100	100
8/5/2011	100	100	86	99.9	100
8/12/2011	92.4	99	91	98.8	99.2
8/19/2011	92.9	98	87	95	99.4
8/25/2011	92.1	100	90.1	98.6	100
9/10/2011	93.5	99.8	89.5	98.3	99.6
9/23/2011	89.6	100	84	98.3	96.2
Mean	**96.1**	**99.7**	**92.2**	**99.1**	**99.5**
Max	100	100	100	100	100
Min	89.6	98	84	95	96.2
Range	10.4	2	16	5	3.8

Table 10. The average percent soil moisture for each treatment replicate during the sampling season in 2010 and 2011. Included are the mean, maximum, minimum, and range for each treatment replicate for each year.

	Replicate 1	**Replicate 2**	**Replicate 3**	**Replicate 4**	**Replicate 5**
East well (m)	74.953	74.98	75.204	74.97	74.945
West well (m)	74.991	74.937	75.238	74.97	74.957
Mean (m)	74.972	74.9585	75.221	74.97	74.951

Table 11. The elevations of each treatment replicate at Kents Creek (IGLD1985), two elevations were used to represent each replicate (east and west ends of the replicate).

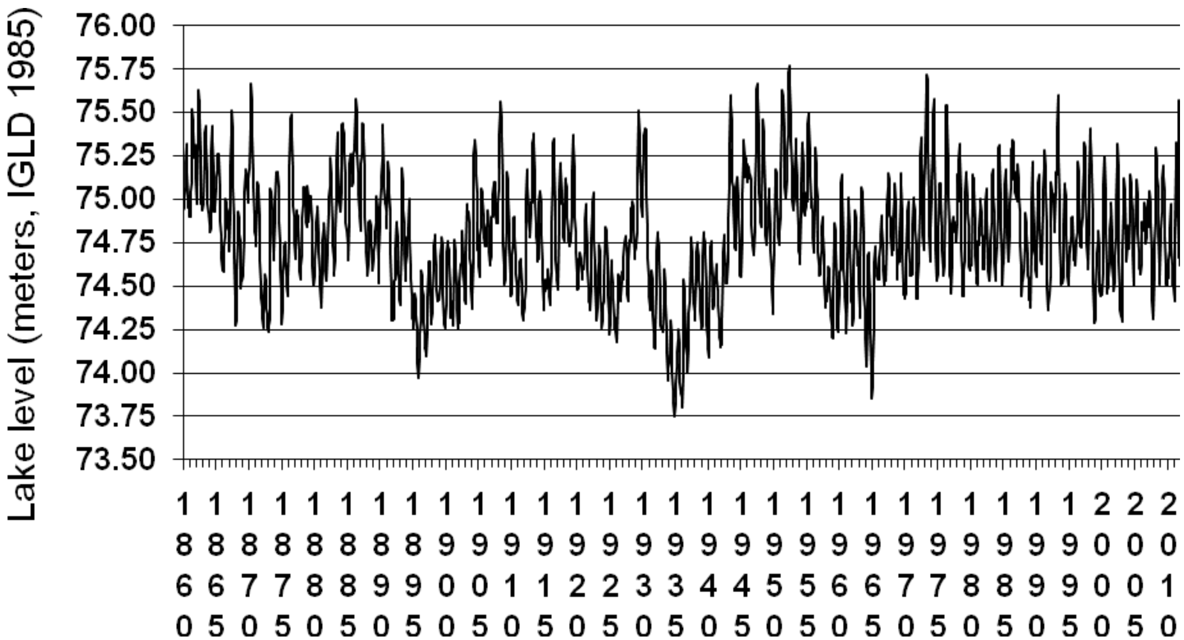

Figure 1. A hydrograph of Lake Ontario showing water levels (meters) from 1860 to 2011. Notice the quasi-periodic cycling nature until the early 1970s. Lake-level regulation stabilized water levels and allowed no low lake levels following the mid-1960s.

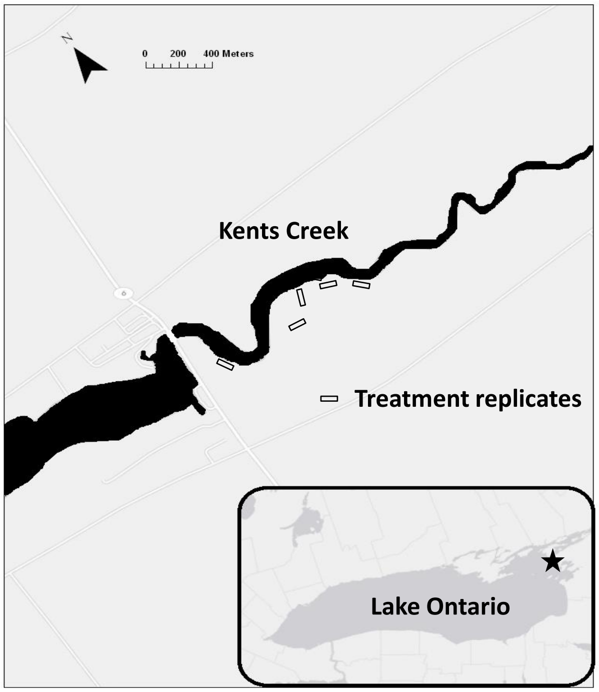

Figure 2. A map of Kents Creek showing the layout of the five treatment replicates. The smaller inset map shows the location of Kents Creek relative to Lake Ontario.

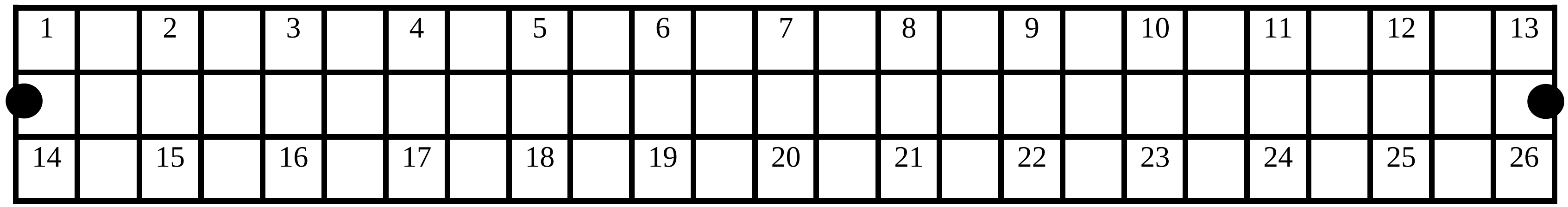

Figure 3. The random placement of each treatment combination within treatment replicate 3. The circles at the right and left of the rectangle represent the placement of the water-table wells for each treatment replicate. Soil core samples were taken near the water-table wells in each replicate. Soil moisture readings were taken in the corner of each treatment plot. The space between each treatment represents the 1m working buffer. Treatment layout: 1=C12W12, 2=C1S1T, 3=C1W12T, 4=C1SW1T, 5=C1S, 6=C12ST, 7=control, 8= C12S, 9=C1W1, 10=C12W1, 11=C12T, 12=C1SW12, 13=control, 14=C1T, 15=C12W12T, 16=C12SW1, 17=C1SW12T, 18=C1SW1, 19=C12, 20=C1W1T, 21=C12SW12, 22=C12SW1T, 23=C12W1T, 24=C12W1T, 25=C1W12, 26=C12SW12T.

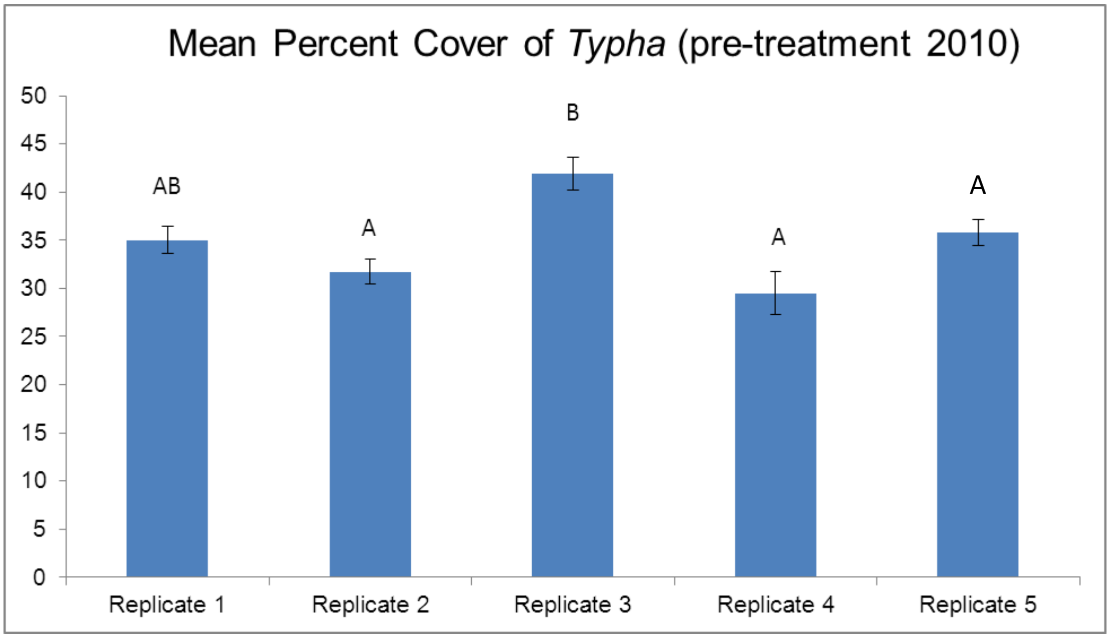

Figure 4. Mean percent cover (± 1 S.E.) of *Typha* for the five replicates at the start of the study. Replicates denoted with the same letter are not significantly different. (ANOVA: F=8.16, df=4, p=0.000).

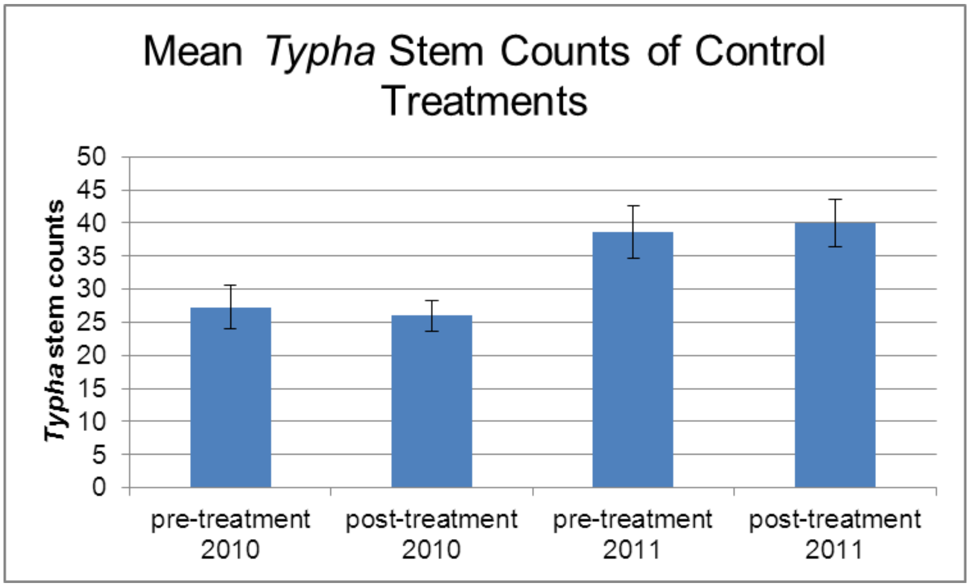

Figure 5. Mean *Typha* stem counts (± 1 S.E.) for control plots across both years of the study and among all five treatment replicates at Kents Creek. Stem counts post-treatment in 2010 were significantly different from those in 2011 (ANOVA: F=4.19, df=3, p=0.012).

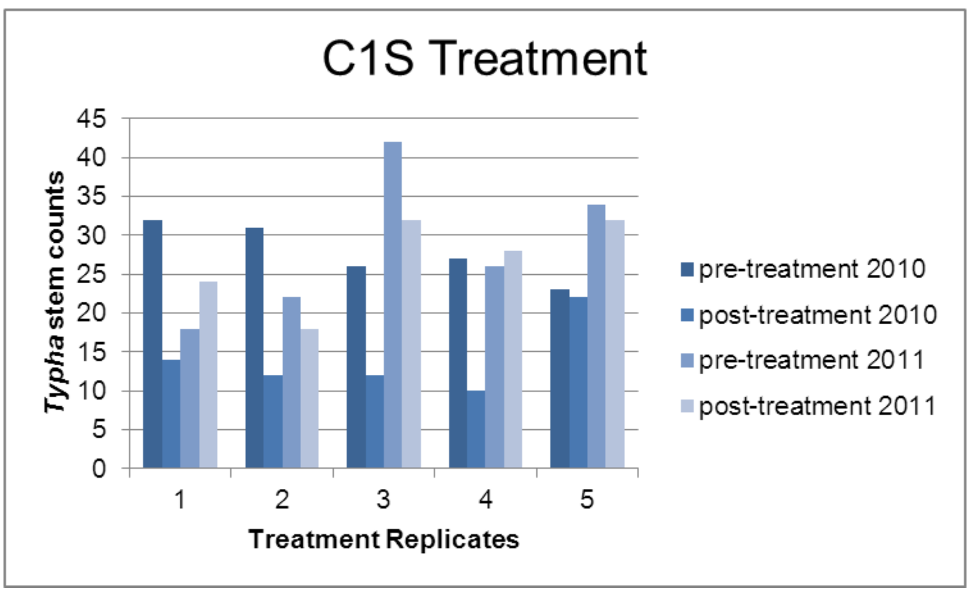

Figure 6. *Typha* stem counts for the C1S treatment for both years and all five treatment replicates at Kents Creek. Post-treatment 2010 stem counts were significantly different than both pre-treatment 2010 and pre-treatment 2011 stem counts (ANOVA: F=5.76, df=3, p=0.007).

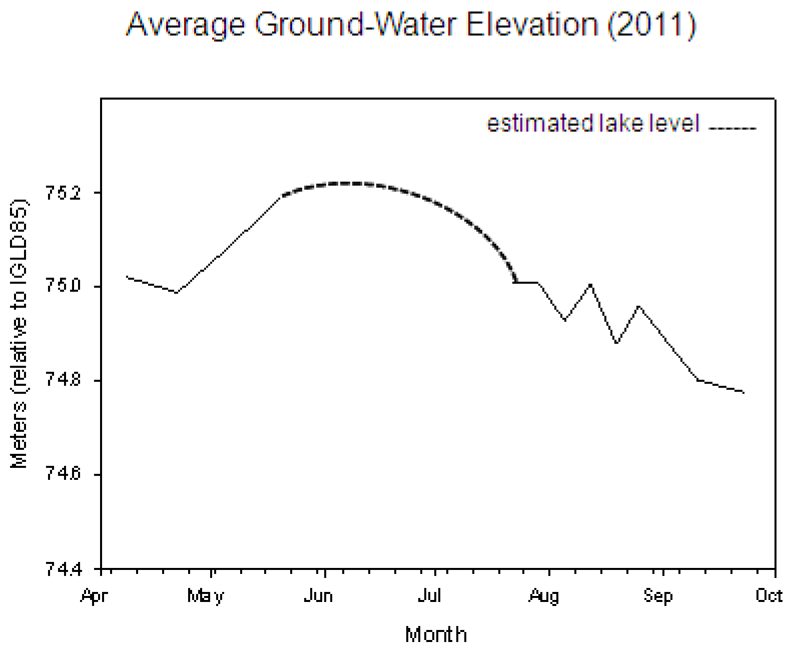

Figure 7. Average ground-water elevation of the five treatment replicates at Kents Creek during the 2011 sampling season. The dotted line represents estimated lake levels during a period when measurements were unable to be taken because water levels were over the top of the wells.

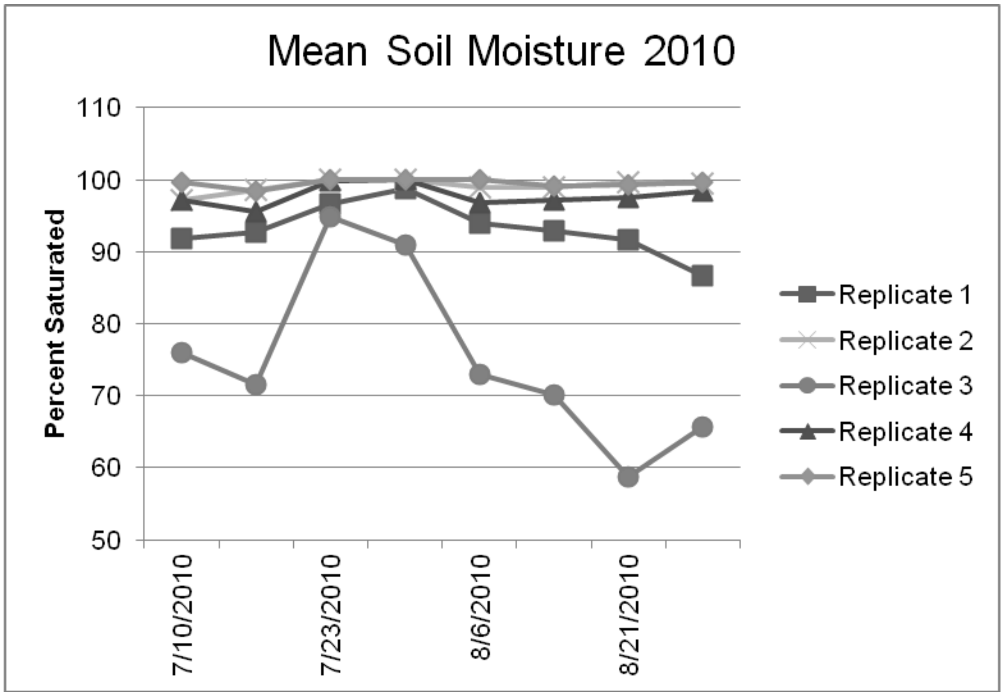

Figure 8. The mean soil moisture for all five treatment replicates at Kents Creek from July to September 2010.

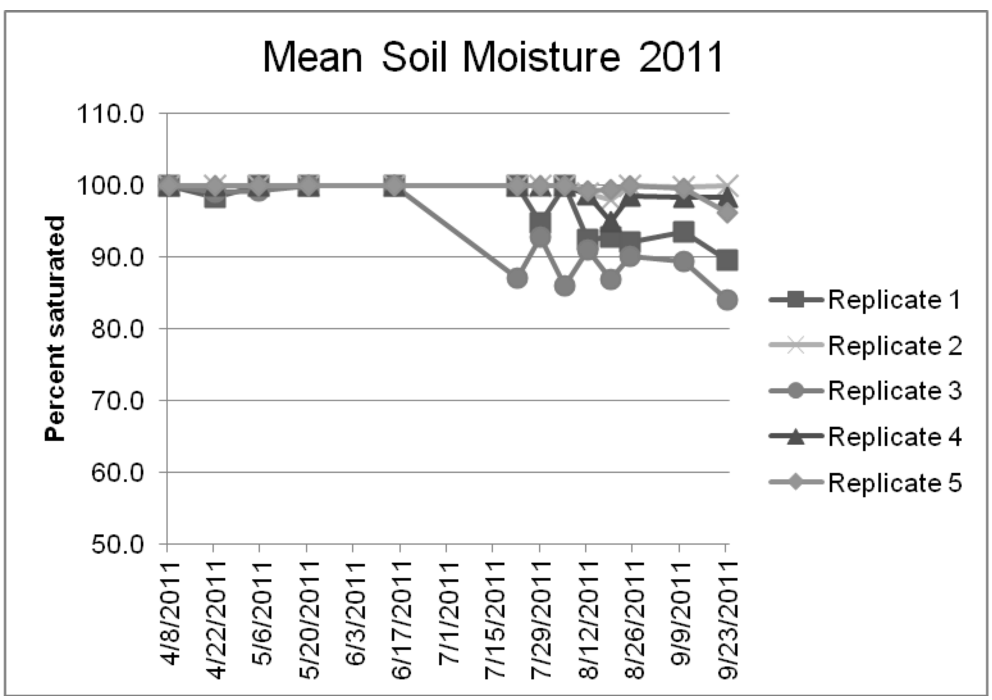

Figure 9. The mean soil moisture for all five treatment replicates at Kents Creek from April through September 2011.

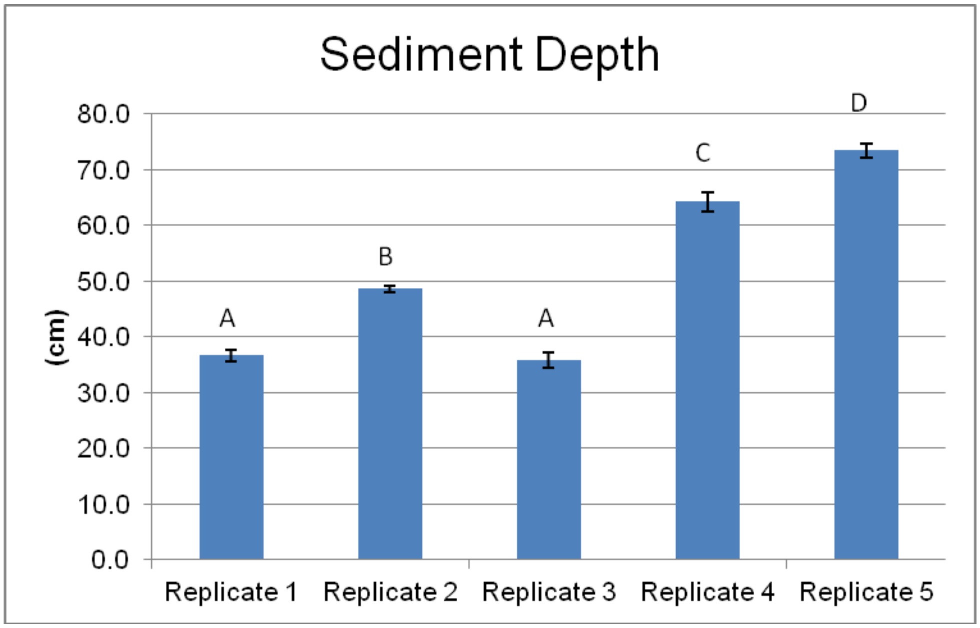

Figure 10. Mean sediment depth for the five treatment replicates at Kents Creek in 2010. (ANOVA: F=170.12, df=4, p=0.000)

Appendix A

<u>Kents Creek species list</u>

Aster seedling

Boehmeria cylindrica (L.) Sw

Calamagrostis canadensis (Michx) P. Beauv

Campanula aparinoides Pursh

Carex lacustris Willd.

Cicuta bulbifera L.

Cirsium arvense (L.) Scop.

Cirsium spp.

Convolvulus arvensis L.

Cornus sericea L.

Epilobium strictum Sprengel

Galium labradoricum (Wiegand) Wiegand

Galium trifidum L.

Hydrocharis morsus-ranae L.

Impatiens capensis Meerb.

Iris versicolor L.

Lactuca spp.

Lathyrus palustris L.

Lemna minor L.

Lycopus americanus W. P. C Barton

Lycopus spp.

Lycopus uniflorus Michaux

Lycopus virginicus L.

Lysimachia thyrsiflora L.

Phalaris arundinacea L.

Phragmites australis (Cav.) Trin. ex Steudel

Polygonum amphibium L.

Polygonum hydropiper L.

Polygonum hydropiperoides Michaux

Rumex orbiculatus A. Gray

Rumex spp.

Scutellaria galericulata L

Solanum dulcamara L.

Sonchus oleraceus L.

Teucrium canadense L.

Typha angustifolia L.

Typha x *glauca* Godr.

Urtica dioica L

Verbena hastata L.

Vitis spp.

Others plants used in the literature:

Ceratophyllum demersum L.

Typha latifolia L.

Nymphaea odorata Ait.

Appendix B

Kents Creek vegetation data (2010 and 2011)

Replicate 1 - 7/11/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
quad	20	15	16	11	6	26	19	7	8	4	2	21	5	14	25	24	22	12	18	1	3	9	17	10	13	23	
total *Typha* stem count	26	32	16	38	24	27	24	45	20	24	29	7	32	26	13	17	18	31	20	38	24	31	23	41	54	17	26.8
Typha angustifolia stem counts	7	13	8	11	8	11	6	15	12	10	10	6	15	8	7	9	10	17	3	5	8	5	6	7	15	8	9.2
Typha x *glauca* stem counts	19	19	8	27	16	16	18	31	8	14	19	1	17	18	6	8	8	14	17	33	16	26	17	34	39	9	17.6
percent covers																											
total percent cover	50	50	70	38	45	50	50	45	50	40	45	50	45	45	55	50	65	55	45	45	35	45	70	40	50	45	49.0
total *Typha*	40	45	35	35	35	30	35	38	40	30	40	15	38	38	20	30	30	40	35	40	28	30	40	40	50	38	35.2
Typha angustifolia	11	18	18	10	12	12	9	13	24	13	14	13	18	12	11	16	17	22	5	5	9	5	10	7	14	18	12.8
Typha x *glauca*	29	27	18	25	23	18	26	26	16	18	26	2	20	26	9	14	13	18	30	35	19	25	30	33	36	20	22.4
Calamagrostis canadensis	12	5	22	3	0	10	8	3	4	5	0	25	0	1	0	8	3	4	5	0	0	20	12	1	1	6	6.1
Carex lacustris	10	3	10	5	4	1	5	4	6	2	1	20	5	6	25	15	25	5	4	5	2	4	5	3	0	10	7.1
Convolvulus arvensis	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2
Galium trifidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0.1
Impatiens capensis	0	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0.3
Iris versicolor	0	0	0	0	0	7	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Lathyrus palustris	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
Lysimachia thyrsiflora	0	3	2	0	1	0	0	0	0	1	2	0	1	2	0	1	0	0	1	2	4	0	1	1	1	0	0.9
Phalaris arundinacea	0	0	4	0	10	0	3	2	0	0	1	2	5	0	8	0	0	5	10	0	1	0	8	0	0	0	2.3
Polygonum amphibium	0	0	2	1	1	3	2	1	1	0	0	0	2	2	0	1	4	1	2	1	1	0.5	3	4	0	0	1.3
Polygonum hydropiperoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.1
Rumex spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.0
Solanum dulcamara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0.1
Teucrium canadense	3	5	5	5	1	1	4	0	4	5	5	5	1	3	0	1	0	1	4	2	4	3	3	5	0	4	2.8

Replicate 2 - 7/11/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	14	5	25	3	16	9	1	26	2	19	10	21	24	20	8	22	15	23	7	18	13	11	12	4	6	17	
total *Typha* stem count	25	31	27	17	22	20	24	31	35	20	13	23	25	26	29	18	23	18	20	26	32	30	29	25	20	25	24.4
Typha angustifolia stem counts	7	4	9	0	5	4	0	16	0	5	7	6	6	4	4	7	4	5	5	6	2	8	7	0	3	0	4.8
Typha x *glauca* stem counts	18	27	18	17	17	16	24	15	35	15	6	17	19	22	25	11	19	13	15	20	30	22	22	25	17	25	19.6
percent covers																											
total percent cover	30	45	50	25	25	40	25	40	40	30	35	40	30	35	40	35	35	35	40	45	25	50	35	40	25	30	35.6
total *Typha*	25	43	45	24	25	30	23	35	38	25	30	30	25	33	35	30	33	30	35	40	25	45	30	38	24	28	31.7
Typha angustifolia	7	6	15	0	6	6	0	18	0	6	16	8	6	5	5	12	6	8	9	9	2	12	7	0	4	0	6.6
Typha x *glauca*	18	37	30	24	19	24	23	17	38	19	14	22	19	28	30	18	27	22	26	31	23	33	23	38	20	28	25.1
Carex lacustris	3	1	3	2	3	8	0	2	0	5	10	9	6	4	2	8	1	4	10	7	0	0	0	3	2	4	3.7
Galium trifidum	4	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	1	4	0	0	0	1	0.4
Impatiens capensis	3	0	2	0	0.5	0.5	1	1	0	1	1	1	1	1	2	3	1	3	0.5	2	1	0	2	1	0	2	1.2
Lysimachia thyrsiflora.	2	3	3	0.5	2	0	2	2	2	0	0	0	1	0	0	0	1	1	0	1	0	0	1	1	1	1	0.9
Phragmites australis	1	5	6	0	0	3	0	4	0	3	0	4	1	0	1	1	0	2	0	0	1	3	0	0	0	0	1.3
Polygonum amphibium	0	0	0	0	0	0	2	0	2	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0.3
Solanum dulcamara	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0.2
Teucrium canadense	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Replicate 3 - 7/11/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	5	14	2	19	8	11	6	9	25	18	12	21	3	4	17	10	1	16	22	24	15	23	26	7	13	
total *Typha* stem count	31	26	28	33	28	38	26	43	42	29	31	37	43	44	28	21	31	41	44	41	47	43	35	29	33	28	34.6
Typha angustifolia stem counts	25	20	19	21	26	34	12	40	40	24	24	34	39	32	23	18	27	26	38	37	35	37	30	26	31	26	28.6
Typha x *glauca* stem counts	6	6	9	12	2	4	14	3	2	5	7	3	4	12	5	3	4	15	6	4	12	6	5	3	2	2	6.0
percent covers																											
total percent cover	50	40	45	65	40	65	40	60	55	60	40	40	55	50	35	35	45	60	45	60	50	55	55	45	55	70	50.6
total *Typha*	43	30	35	50	35	55	30	58	48	50	35	35	50	45	31	28	38	50	40	45	48	48	50	40	48	25	41.9
Typha angustifolia	35	23	24	32	33	49	14	54	46	41	27	32	45	33	25	24	33	32	35	41	36	41	43	36	45	23	34.6
Typha x *glauca*	8	7	11	18	3	6	16	4	2	9	8	3	5	12	6	4	5	18	5	4	12	7	7	4	3	2	7.3
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	40	1.7
Carex lacustris	7	0	8	5	3	8	10	1	7	8	4	2	5	1	0	5	1	0	1	10	6	4	5	7	5	10	4.7
Cirsium arvense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0
Convolvulus arvensis	0	0	0	0	0	0	1	1	0	1	0	3	0	0	0	0	1	0	1	0	1	0	0	2	3	6	0.8
Impatiens capensis	2	1	2	3	2	6	1	1	5	2	3	0	2	2	2	3	1	4	3	3	2	3	2	2	2	0	2.3
Lathyrus palustris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0
Lysimachia thyrsiflora	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Polygonum amphibium	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.1
Teucrium canadense	0	2	2	1	3	8	3	2	4	5	3	0	2	3	2	1	5	4	0	3	1	6	1	1	1	2	2.5
Verbena hastata	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4

Replicate 4 - 7/11/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	4	3	10	1	15	8	6	11	16	14	24	7	5	21	20	13	12	17	9	26	19	25	23	18	22	2	
total *Typha* stem count	37	27	19	32	19	20	35	30	16	30	29	37	29	23	31	27	36	14	24	32	29	12	22	22	22	17	25.8
Typha angustifolia stem counts	34	25	13	32	14	13	30	26	11	27	23	30	27	22	31	25	23	11	19	27	27	9	20	18	18	16	22.0
Typha x *glauca* stem counts	3	2	6	0	5	7	5	4	5	3	6	7	2	1	0	2	13	3	5	5	2	3	2	4	4	1	3.8
percent covers																											
total percent cover	52	50	30	75	80	50	50	40	60	70	55	25	45	50	53	40	45	64	45	55	40	30	40	30	50	70	49.8
total *Typha*	20	40	25	25	15	30	45	35	10	30	40	18	40	44	48	30	43	18	38	42	35	12	30	20	20	15	29.5
Typha angustifolia	18	37	17	25	11	20	39	30	7	27	32	15	37	42	48	28	27	14	30	35	33	9	27	16	16	14	25.2
Typha x *glauca*	2	3	8	0	4	11	6	5	3	3	8	3	3	2	0	2	16	4	8	7	2	3	3	4	4	1	4.3
Bohemaria cylindrica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.1
Calamagrostis canadensis	0	8	3	0	65	8	1	1	45	40	2	3	0	3	1	0	0	40	7	10	2	3	4	2	25	45	12.2
Carex lacustris	0	0	0	0	0	0	0	0	0	0	8	0	0	2	3	4	0	0	0	2	0	6	2	0	1	0	1.1
Galium trifidum	1	0	0	1	0	1	1	0	0	3	0	1	1	1	1	1	1	1	1	0	1	0	1	1	0	2	0.8
Impatien capensis	1	1	1	0	1	3	1	1	1	1	3	1	0	2	2	1	1	0	2	2	1	1	3	2	1	2	1.3
Lactuca spp.	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Lycopus spp.	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Lysimachia thyrsiflora	1	1	1	1	2	0	2	1	1	2	1	1	2	2	1	0	0	2	0	0	3	2	1	2	0	0	1.1
Polygonum amphibium	1	0	0	0	0	2	1	1	1	1	0	0	1	2	1	1	0	2	1	1	0	1	1	2	1	1	0.8
Polygonum hydropiper	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8
Teucrium canadense	1	0	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	2	0	2	1	1	0	1	0	1	0.5

Replicate 5 - 7/11/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	16	23	1	24	25	20	21	17	9	4	3	18	15	26	22	2	8	19	10	14	6	13	12	7	5	11	
total *Typha* stem count	29	23	19	33	21	27	30	24	27	24	26	29	22	34	28	26	31	32	19	23	32	30	29	27	29	28	27.0
Typha angustifolia stem counts	23	6	3	6	7	13	11	17	7	14	19	25	17	7	5	23	9	26	6	15	7	4	4	8	6	4	11.2
Typha x *glauca* stem counts	6	17	16	27	14	14	19	7	20	10	7	4	5	27	23	3	22	6	13	8	25	26	25	19	23	24	15.8
percent covers																											
total percent cover	37	30	45	40	40	40	40	50	30	35	40	45	58	40	35	40	40	60	25	50	30	30	30	40	35	30	39.0
total *Typha*	35	30	38	38	30	38	38	45	30	30	38	40	48	38	35	35	40	55	25	40	28	28	28	39	35	30	35.9
Typha angustifolia	28	8	6	7	10	18	14	32	8	18	28	34	37	8	6	31	12	45	8	26	6	4	4	12	7	4	16.1
Typha x *glauca*	7	22	32	31	20	20	24	13	22	13	10	6	11	30	29	4	28	10	17	14	22	24	24	27	28	26	19.8
Carex lacustris	1	1	10	1	6	3	2	5	0	5	1	5	7	5	0	5	0	2	0	8	3	2	0.5	0	0	1	2.8
Impatiens capensis	1	0.5	1	1	2	1	0	2	0	0	0	0	3	3	1	0	0	1	0	2	0	0	0	0	0	0.5	0.7
Lysimachia thyrsiflora	0	0.5	0	2	2	3	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	4	2	0	0.5	0.7
Polygonum amphibium	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	2	1	0	1	0	0	0	0.3
Teucrium canadense	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1

Replicate 1 - 8/23/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	15	16	11	6	26	19	7	8	4	2	21	5	14	25	24	22	12	18	1	3	9	17	10	13	23	
total *Typha* stem count	15	14	1	18	18	23	18	21	9	20	25	3	16	11	0	5	6	17	11	26	5	19	6	32	42	20	15.4
Typha angustifolia stem counts	5	5	1	18	10	10	12	21	3	7	6	1	10	11	0	4	3	9	6	4	3	19	3	13	15	5	7.8
Typha x *glauca* stem counts	10	9	0	0	8	13	6	0	6	13	19	2	6	0	0	1	3	8	5	22	2	0	3	19	27	15	7.6
percent covers																											
total percent cover	95	45	95	30	70	70	75	30	80	60	15	95	60	50	80	80	95	90	85	25	45	50	80	35	95	95	66.3
total *Typha*	15	18	1	20	20	25	25	18	10	15	12	2	12	20	0	3	5	25	20	20	5	18	5	20	70	40	17.1
Typha angustifolia	5	6	1	20	11	11	17	18	3	5	3	1	8	20	0	2	3	13	11	3	3	18	3	8	25	10	8.7
Typha x *glauca*	10	12	0	0	9	14	8	0	7	10	9	1	5	0	0	1	3	12	9	17	2	0	3	12	45	30	8.3
Calamagrostis canadensis	65	20	60	10	4	40	20	5	10	20	0	60	2	5	55	40	45	30	30	0	0	30	60	1	30	30	25.8
Campanula aparinoides	3	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0.2
Carex lacustris	5	0	20	3	10	5	25	2	20	8	1	10	5	20	20	15	35	20	2	3	12	12	8	1	20	20	11.6
Cicuta bulbifera	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Convolvulus arvensis	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Cornus sericea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0.1
Galium labradoricum	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	1	0	0	0	0	0	0	1	0	0.1
Galium trifidum	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0.5	0	0	0	0.5	0	0.5	0.5	0	0.1
Impatiens capensis	2	2	3	0	0	0	10	0	5	3	0	5	0	0	0	2	2	0	2	0	0	2	0	0	0	0	1.5
Iris versicolor	1	0	0	0	0	10	1	2	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.8
Lathyrus palustris	1	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0.3
Lycopus americanus	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0.2
Lycopus uniflorus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0.3
Lycopus virginicus	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Lysimachia thyrsiflora	1	0	0.5	0.5	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0.5	0	0	0.2
Phalaris arundinacea	3	0	1	0	35	5	0	0	0	0	0.5	20	15	0	10	2	0	15	25	0	2	0	8	0	15	6	6.3
Polygonum amphibium	3	2	6	0	2	6	0	3	1	4	0	3	15	3	2	4	4	1	0	1	0.5	1	3	20	1	10	3.7
Polygonum hydropiper	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rumex orbiculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0.5
Scuttellaria galericulata	0	0	0	0	0	1	3	0	0	0	0	0	0	8	0	0	0	0.5	0	0	0	0	0	0	0.5	0	0.5
Teucrium canadense	20	20	2	0.5	0	0	2	0	4	5	3	4	0	3	6	4	4	0	10	0	10	1	3	0	0	10	4.3

Replicate 2 - 8/23/2010																										
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	14	5	25	3	16	9	1	26	2	19	10	21	24	20	8	22	15	23	7	18	13	11	12	4	6	17	
total *Typha* stem count	28	12	12	22	17	15	47	33	28	7	3	6	15	20	22	6	22	11	6	7	44	20	17	27	21	25	19.0
Typha angustifolia stem counts	18	2	10	12	5	6	41	23	8	2	1	1	11	17	20	5	8	6	4	0	25	7	15	10	6	15	10.7
Typha x *glauca* stem counts	10	10	2	10	12	9	6	10	20	5	2	5	4	3	2	1	14	5	2	7	19	13	2	17	15	10	8.3
percent covers																											
total percent cover	50	35	50	30	35	30	45	35	25	40	40	40	35	40	20	20	35	50	35	30	45	45	30	35	40	60	37.5
total *Typha*	30	10	20	20	20	15	35	30	20	4	3	3	10	25	15	10	25	10	8	3	40	25	15	25	30	50	19.3
Typha angustifolia	19	2	17	11	6	6	31	21	6	1	1	1	7	21	14	8	9	5	5	0	23	9	13	9	9	30	10.9
Typha x *glauca*	11	8	3	9	14	9	4	9	14	3	2	3	3	4	1	2	16	5	3	3	17	16	2	16	21	20	8.4
Carex lacustris	25	8	20	10	20	20	0	4	0	30	30	30	15	20	4	8	12	35	30	30	3	8	0	10	10	10	15.1
Galium trifidum	0.5	0	0	0.5	1	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0.5	0	0.5	0.2
Impatiens capensis	3	0	8	0	1	0	0.5	1	0	3	1	0	3	2	0.5	0.5	2	10	0	1	1	1	0	0	0	2	1.6
Lathyrus palustris	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.1
Lycopus uniflorus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Lysimachia thyrsiflora	0	5	6	1	4	0	2	1	4	0	0	0	0	1	0	0	2	2	0	0	0	0	1	1	1	1	1.2
Phragmites australis	0	4	15	0	0	15	0	2	0	10	5	10	7	2	0.5	1	0	8	25	0	3	15	4	0	0	0	4.9
Polygonum amphibium	8	0	0	0	0	0	4	0	8	0	0	0	2	0	0	0	0	2	0	0	0	3	0	0	0	0	1.0
Scuttellaria galariculata	3	0	0	0	1	0	1	0	0.5	0	0	0	4	0	0	0	0	2	0	0	2	0	0	0	0	0	0.5
Solanum dulcamara	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0.5
Verbena hastata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0.1

Replicate 3 - 8/23/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	5	14	2	19	8	11	6	9	25	18	12	21	3	4	17	10	1	16	22	24	15	23	26	7	13	
total *Typha* stem count	16	12	5	10	15	15	10	14	20	10	16	21	15	22	11	13	24	27	14	22	14	15	11	5	34	22	15.9
Typha angustifolia stem counts	11	9	5	6	15	9	5	14	15	5	6	15	14	14	11	13	9	6	4	10	9	14	11	5	34	14	10.9
Typha x *glauca* stem counts	5	3	0	4	3	6	5	0	5	5	10	6	1	8	0	0	15	21	10	12	5	1	0	0	0	8	5.1
percent covers																											
total percent cover	35	10	60	25	45	30	40	6	40	80	30	30	45	30	8	35	35	40	10	40	30	50	10	35	80	90	37.3
total *Typha*	6	10	5	10	12	20	8	6	20	6	10	10	10	20	7	6	20	25	5	10	10	15	6	3	75	35	14.2
Typha angustifolia	4	8	5	6	12	12	4	6	15	3	4	7	9	13	7	6	8	6	1	5	6	14	6	3	75	22	10.2
Typha x *glauca*	2	3	0	4	2	8	4	0	5	3	6	3	1	7	0	0	13	19	4	5	4	1	0	0	0	13	4.1
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	30	1.6
Carex lacustris	30	0	10	5	10	6	20	1	15	35	3	3	25	5	0	12	6	0	2	30	10	8	5	12	5	30	11.1
Cirsium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0.1
Convolvulus arvensis	0	0	0	0	0	0	1	0	0	1	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	1	0.2
Cornus sericea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.0
Impatiens capensis	2	1	15	1	4	3	2	0	8	3	0	0	4	0	0.5	4	2	1	1	3	1	4	0	0	8	2	2.7
Lathyrus palustris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0.0
Lysimachia thyrsiflora	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.1
Polygonum amphibium	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	10	0	0	0.6
Teucrium canadense	1	3	30	4	25	4	30	0.5	6	30	3	2	2	6	2	4	30	25	1	2	1	30	1	10	2	5	10.0
Urtica dioica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0
Vitis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.0

Replicate 4 - 8/23/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	4	3	10	1	15	8	6	11	16	14	24	7	5	21	20	13	12	17	9	26	19	25	23	18	22	2	
total *Typha* stem count	27	10	25	14	7	16	40	21	12	17	16	14	35	21	20	28	40	7	14	26	35	19	9	12	25	16	20.2
Typha angustifolia stem counts	23	6	22	14	2	13	40	19	7	17	13	10	33	19	19	27	25	3	14	18	32	18	4	9	13	11	16.6
Typha x *glauca* stem counts	4	4	3	0	5	3	0	2	5	0	3	4	2	2	1	1	15	4	0	8	3	1	5	3	12	5	3.7
percent covers																											
total percent cover	30	10	35	60	95	25	45	30	95	95	35	10	40	60	35	30	45	90	35	30	45	50	30	35	95	95	49.2
total *Typha*	25	6	25	10	3	20	40	25	5	15	8	7	35	25	15	25	45	4	8	8	25	25	10	8	30	30	18.5
Typha angustifolia	21	4	22	10	1	16	40	23	3	15	7	5	33	23	14	24	28	2	8	6	23	24	4	6	16	21	15.3
Typha x *glauca*	4	2	3	0	2	4	0	2	2	0	2	2	2	2	1	1	17	2	0	2	2	1	6	2	14	9	3.3
Aster seedling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.0
Calamagrostis canadensis	0	3	10	1	90	10	0	0	90	70	12	0.5	0	10	2	0	0	80	25	20	10	10	15	20	65	80	24.0
Campanula aparinoides	0	0	0	0	1	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.1
Carex lacustris	0	0	0	0	0	8	0	1	0	0	12	0	0	8	15	3	0	0	0	0	0	15	5	0	5	0	2.8
Cicuta bulbifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0.1
Epilobium strictum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Galium trifidum	1	0	0.5	0	0	1	0.5	0.5	0	2	0	0.5	1	1	0.5	0	1	0.5	0.5	0	10	0.5	1	0.5	0	10	1.3
Impatiens capensis	2	0.5	0.5	0	4	4	1	0	1	3	0	0	2	4	3	0.5	0.5	2	0	1	6	3	3	0	0	5	1.8
Lycopus americanus	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0.1
Lysimachia thyrsiflora	0	1	0.5	0.5	1	1	0	0.5	1	0	1	0.5	0	1	0.5	0	0	2	0	0	1	0	0.5	0	0	0	0.5
Phalaris arundinacea	0	0	0	0	0	4	0	1	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0.5
Polygonum amphibium	15	2	10	4	0	15	20	12	2	1	1	10	15	15	2	0	4	8	6	8	6	5	6	12	12	15	7.9
Polygonum hydropiper	0	0	0	50	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.0
Rumex orbiculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.0
Scutellaria galericulata	1	0	0	0	1	1	0	0	0	2	0	0	1	1	1	0.5	1	0	0.5	0	3	0	0.5	1	0	0.5	0.6
Sonchus oleraceus	0	0	0	2	0.5	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
Teucrium canadense	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0.2
Urtica dioica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0.2

Replicate 5 - 8/23/2010																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	16	23	1	24	25	20	21	17	9	4	3	18	15	26	22	2	8	19	10	14	6	13	12	7	5	11	
total *Typha* stem count	25	22	17	33	15	16	38	28	35	19	28	16	28	40	33	20	30	28	18	22	26	30	36	32	31	24	26.5
Typha angustifolia stem counts	7	20	8	18	8	6	28	23	29	6	10	6	23	35	25	15	25	12	10	10	12	20	31	25	20	21	17.4
Typha x *glauca* stem counts	18	2	9	15	7	10	10	5	6	13	18	10	5	5	8	5	5	16	8	12	14	10	5	7	11	3	9.1
percent covers																											
total percent cover	40	25	50	40	50	35	45	35	35	30	25	30	60	50	30	25	35	45	15	45	35	40	35	30	65	50	38.5
total *Typha*	35	25	30	40	20	25	40	30	35	20	25	20	40	45	30	25	35	40	15	25	25	35	30	30	65	50	32.1
Typha angustifolia	10	23	14	22	11	9	29	25	29	6	9	8	33	39	23	19	29	17	8	11	12	23	26	23	42	44	20.9
Typha x *glauca*	25	2	16	18	9	16	11	5	6	14	16	13	7	6	7	6	6	23	7	14	13	12	4	7	23	6	11.2
Carex lacustris	4	0.5	25	2	30	10	4	4	0	10	1	10	25	3	0	3	0	3	0	10	10	5	5	0	0	0	6.3
Cicuta bulbifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0.5	0.5	0	0	0.1
Impatiens capensis	1	0.5	0.5	0.5	8	1	1	0	0	0	0	0	6	3	1	0	0	1	0	2	0	0.5	0	0	0	1	1.0
Lysimachia thyrsiflora	0	0.5	0	2	2	2	2	0	0	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0	0	1	0	0.5	0.4
Polygonum amphibium	0	0	0	0	6	0	0	0	2	0	2	0.5	2	3	0	1	0	2	0	20	0	2	0	0	0	2	1.6
Scuttelaria galericulata	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1

Replicate 1 - 6/30/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	15	16	11	6	26	19	7	8	4	2	21	5	14	25	24	22	12	18	1	3	9	17	10	13	23	
total *Typha* stem count	34	18	17	40	46	37	36	31	15	19	11	8	18	22	11	14	20	29	8	10	13	16	18	26	62	23	23.2
Typha angustifolia stem counts	5	0	12	5	12	12	12	0	2	0	10	0	5	8	0	0	5	8	0	2	3	0	4	10	20	2	5.3
Typha x *glauca* stem counts	29	18	5	35	34	25	24	31	13	19	1	8	13	14	11	14	15	21	8	8	10	16	14	16	42	21	17.9
percent covers																											
total percent cover	70	45	60	55	85	50	75	40	75	65	25	75	50	45	70	65	65	75	50	15	58	30	80	40	85	70	58.4
total *Typha*	45	38	20	45	50	30	50	35	15	25	25	8	25	25	10	10	20	40	8	15	30	15	15	35	70	30	28.2
Typha angustifolia	7	0	14	6	13	10	17	0	2	0	23	0	7	9	0	0	5	11	0	3	7	0	3	13	23	3	6.7
Typha x *glauca*	38	38	6	39	37	20	33	35	13	25	2	8	18	16	10	10	15	29	8	12	23	15	12	22	47	27	21.5
Calamagrostis canadensis	5	3	10	5	5	20	10	2	2	5	0	15	0	3	5	4	15	5	3	0	0	5	15	1	10	15	6.3
Carex lacustris	25	13	25	5	4	0	20	1	20	30	0	25	3	15	45	45	20	3	10	1	6	8	15	3	5	20	14.1
Hydrocharis morsus-ranae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0.2
Iris versicolor	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2
Lathyrus palustris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1
Lemna minor	1	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	1	1	1	1	0	0	0.5
Lycopus americanus	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.3
Lysimachia thyrsiflora	1	1	0	0	0	0	2	0	0	0	1	1	2	2	0	0	0	0	1	0	1	0	1	0	0	0	0.5
Phalaris arundinacea	8	0	2	0	30	4	4	3	0	2	0	20	25	0	0	0	0	30	30	0	25	0	30	0	1	0	8.2
Polygonum amphibium	0	0	1	0	0	4	0	3	2	2	0	2	1	4	3	5	4	0	0	3	1	4	3	6	0	0	1.8
Rumex spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	1.0
Teucrium canadense	3	5	2	0	1	1	5	1	1	5	1	4	0	5	2	4	3	2	0	1	4	0	5	1	0	1	2.2
unknown 1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Replicate 2 - 6/30/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	14	5	25	3	16	9	1	26	2	19	10	21	24	20	8	22	15	23	7	18	13	11	12	4	6	17	
total *Typha* stem count	37	22	40	33	30	15	47	52	37	27	12	17	24	23	14	22	38	26	16	20	16	19	18	16	27	34	26.2
Typha angustifolia stem counts	9	0	4	12	12	9	10	15	8	10	8	3	4	8	7	10	12	12	4	3	6	8	5	5	6	10	7.7
Typha x *glauca* stem counts	28	22	36	21	18	6	37	37	29	17	4	14	20	15	7	12	26	14	12	17	10	11	13	11	21	24	18.5
percent covers																											
total percent cover	65	45	75	45	65	45	45	55	45	55	35	50	50	40	35	30	60	65	40	45	75	45	35	25	50	70	49.6
total *Typha*	55	25	55	40	55	30	40	55	35	30	30	40	45	35	30	20	50	50	30	35	55	20	30	15	35	60	38.5
Typha angustifolia	13	0	6	15	22	18	9	16	8	11	20	7	8	12	15	9	16	23	8	5	21	8	8	5	8	18	11.8
Typha x *glauca*	42	25	50	25	33	12	31	39	27	19	10	33	38	23	15	11	34	27	23	30	34	12	22	10	27	42	26.7
Carex lacustris	0	5	15	10	20	8	0	3	0	25	6	12	12	5	5	5	10	25	10	20	0	8	2	8	8	20	9.3
Galium trifidum	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2
Hydrocharis morsus-ranae	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
Lysimachia thyrsiflora	5	2	10	0	4	0	4	1	10	0	0	0	3	0	0	1	3	2	0	1	1	5	1	1	1	1	2.2
Phragmites australis	0	10	15	0	0	10	1	1	0	0	2	5	5	1	0	2	0	5	0	0	0	15	8	0	0	0	3.1
Polygonum amphibium	6	0	0	0	0	0	4	0	3	0	2	0	3	0	0	0	3	1	0	0	0	0	0	0	0	0	0.8
Solanum dulcamara	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0.2
Teucrium canadense	2	0	0	1	1	0	1	1	1	1	0	0	2	0	0	1	0	1	0	0	1	1	0	0	0	1	0.6

Replicate 3 - 6/30/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	5	14	2	19	8	11	6	9	25	18	12	21	3	4	17	10	1	16	22	24	15	23	26	7	13	
total *Typha* stem count	37	42	38	36	31	27	20	46	39	24	28	21	28	26	31	17	33	33	29	20	22	23	22	21	57	46	30.7
Typha angustifolia stem counts	12	9	5	12	8	0	9	12	10	9	0	10	7	7	10	0	0	5	6	6	4	12	7	10	20	18	8.0
Typha x *glauca* stem counts	25	33	33	24	23	27	11	34	29	15	28	11	21	19	21	17	33	28	23	14	18	11	15	11	37	28	22.7
percent covers																											
total percent cover	85	55	65	45	65	50	55	60	60	45	45	35	75	35	30	50	45	45	50	40	70	45	35	65	95	85	55.0
total *Typha*	40	50	45	40	50	40	25	50	50	30	40	30	30	35	25	20	40	40	40	20	50	35	15	20	95	75	39.6
Typha angustifolia	13	11	6	13	13	0	11	13	13	11	0	14	8	9	8	0	0	6	8	6	9	18	5	10	33	29	10.3
Typha x *glauca*	27	39	39	27	37	40	14	37	37	19	40	16	23	26	17	20	40	34	32	14	41	17	10	10	62	46	29.3
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	3	0	0	0	0	2	0	30	1.6
Carex lacustris	40	0	25	3	15	8	30	12	10	15	4	3	40	1	0	30	4	0	6	20	30	10	5	35	4	5	13.7
Cirsium arvense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.0
Convolvulus arvensis	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0.2
Impatiens capensis	0	1	0	1	0	1	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	0	1	0	0.5
Lysimachia thyrsiflora	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.1
Polygonum amphibium	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0.1
Rumex spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.0
Teucrium canadense	2	12	2	10	7	5	3	4	8	2	5	6	8	2	10	3	10	5	5	8	10	5	8	3	3	2	5.7
unknown aster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0
Verbena hastata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0.2

Replicate 4 - 6/30/2011																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	9.1	10.1	11.1	12.1	13.1	14.1	151	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	4	3	10	1	15	8	6	11	16	24	5	20	12	9	19	23	14	7	21	13	17	26	25	18	22	2	
total *Typha* stem count	55	26	34	27	19	47	49	35	19	26	22	20	24	20	7	13	14	23	16	16	9	27	7	15	32	24	24.1
Typha angustifolia stem counts	15	5	15	10	6	15	10	15	5	0	8	5	7	2	0	0	0	9	5	5	2	8	0	5	10	12	6.7
Typha x *glauca* stem counts	40	21	19	17	13	32	39	20	14	26	14	15	17	18	7	13	14	14	11	11	7	19	7	10	22	12	17.4
percent covers																											
total percent cover	55	45	50	40	75	40	60	45	60	40	30	40	30	35	15	50	45	30	40	10	70	45	45	35	90	75	46.0
total *Typha*	50	40	35	30	15	30	55	40	12	25	25	30	25	10	8	15	15	25	30	10	5	40	10	20	40	30	25.8
Typha angustifolia	14	8	15	11	5	10	11	17	3	0	9	8	7	1	0	0	0	10	9	3	1	12	0	7	13	15	7.2
Typha x *glauca*	36	32	20	19	10	20	44	23	9	25	16	23	18	9	8	15	15	15	21	7	4	28	10	13	28	15	18.5
Calamagrostis canadensis	0	4	15	8	65	3	0	0	50	2	0	0	0	15	5	30	30	0	2	0	65	5	5	8	45	45	15.5
Carex lacustris	0	0	2	0	0	0	0	5	0	8	0	10	3	4	0	12	0	0	6	2	0	1	30	0	6	0	3.4
Galium trifidum	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0.2
Hydrocharis morsus-ranae	1	0	1	1	0	0	1	1	0	1	0	0	0	2	0	0	0	1	3	2	1	1	1	2	0	0	0.7
Lemna minor	0	1	1	0	0	1	1	1		0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0.3
Lysimachia thyrsiflora	0	0	1	3	1	1	2	1	2	5	3	2	1	1	3	1	1	3	2	0	5	0	1	1	1	1	1.6
Phalaris arundinacea	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0.3
Polygonum amphibium	5	3	5	2	1	3	5	3	0	1	5	1	3	3	5	5	1	8	7	2	0	3	3	5	3	1	3.2
Rumex spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0.1
Teucrium canadense	1	0	0	1	1	0	0	0	1	0	1	1	0	0	0	1	1	1	1	0	1	2	0	1	0	1	0.6
unknown 2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Replicate 5 - 6/30/2011																														
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	16	23	1	24	25	20	21	17	9	4	3	18	15	26	22	2	8	19	10	14	6	13	12	7	5	11	
total *Typha* stem count	53	34	36	35	23	32	52	36	10	15	15	25	27	19	7	13	13	24	23	16	17	14	12	15	42	39	24.9
Typha angustifolia stem counts	5	0	10	6	5	6	12	13	4	10	5	5	10	5	7	4	5	6	10	5	8	0	3	10	15	10	6.9
Typha x *glauca* stem counts	48	34	26	29	18	26	40	23	6	5	10	20	17	14	0	9	8	18	13	11	9	14	9	5	37	29	18.4
percent covers																											
total percent cover	70	45	55	60	65	50	65	50	10	12	10	40	45	35	6	20	10	40	15	35	25	15	8	12	45	50	34.3
total *Typha*	65	45	40	55	35	45	60	40	10	10	10	40	40	30	6	15	10	35	15	20	15	10	6	12	45	50	29.4
Typha angustifolia	6	0	11	9	8	8	14	14	4	7	3	8	15	8	6	5	4	9	7	6	7	0	2	8	16	13	7.6
Typha x *glauca*	59	45	29	46	27	37	46	26	6	3	7	32	25	22	0	10	6	26	8	14	8	10	5	4	40	37	22.2
Carex lacustris	8	1	20	6	20	20	8	10	0	4	1	1	5	6	0	8	0	7	0	15	15	6	4	0	0	2	6.4
Lemna minor	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0.2
Lysimachia thyrsiflora	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	1	0.3
Polygonum amphibium	2	0	0	0	1	0	0	0	1	0	1	2	1	2	0	0	0	0	0	3	2	1	0	0	0	3	0.7

Replicate 1 - 8/25/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	15	16	11	6	26	19	7	8	4	2	21	5	14	25	24	22	12	18	1	3	9	17	10	13	23	
total *Typha* stem count	31	24	19	39	28	34	23	34	14	18	18	8	20	19	13	13	17	20	4	8	14	21	12	34	60	26	22.0
Typha angustifolia stem counts	0	0	0	0	0	0	2	0	0	5	3	0	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0.6
Typha x *glauca* stem counts	31	24	19	39	28	34	21	34	14	13	15	8	18	19	13	13	17	20	4	8	14	18	12	34	60	26	21.4
percent covers																											
total percent cover	95	75	75	85	95	80	80	50	90	80	50	90	80	75	80	80	90	90	60	15	85	70	65	60	100	85	76.2
total *Typha*	30	30	25	50	20	15	15	30	20	25	40	10	25	25	10	15	15	15	5	10	10	20	5	45	80	35	24.0
Typha angustifolia	0	0	0	0	0	0	1	0	0	7	7	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0.8
Typha x *glauca*	30	30	25	50	20	15	14	30	20	18	33	10	23	25	10	15	15	15	5	10	10	17	5	45	80	35	23.3
Calamagrostis canadensis	10	20	40	35	0	65	20	10	5	10	0	20	10	2	45	20	20	25	10	0	5	20	20	1	25	25	17.8
Carex lacustris	25	15	10	5	25	5	20	5	40	20	5	25	15	50	35	30	60	40	8	2	40	20	15	3	3	25	21.0
Convolvulus arvensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.0
Iris versicolor	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2
Lathyrus palustris	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0.2
Lemna minor	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0.2
Lycopus americanus	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0.5
Lysimachia thyrsiflora	0	0	0	0	2	0	1	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0.3
Phalaris arundinacea	30	0	0	0	50	5	35	0	0	0	0	30	25	1	0	0	0	25	45	0	15	0	30	0	0	0	11.2
Polygonum amphibium	6	6	4	2	0	8	0	20	10	8	5	5	5	3	3	10	6	0	0	3	6	10	1	20	0	0	5.4
Rumex spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0.4
Scuttelaria galericulata	0	2	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Teucrium canadense	0	5	1	0	0	1	5	3	2	3	1	3	0	2	5	6	3	2	1	1	10	0	3	0	0	2	2.3
unknown 1	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1

Replicate 2 - 8/25/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	14	5	25	3	16	9	1	26	2	19	10	21	24	20	8	22	15	23	7	18	13	11	12	4	6	17	
total *Typha* stem count	35	18	33	29	23	15	35	42	35	30	12	17	26	20	22	21	33	23	14	23	22	12	17	13	30	39	24.6
Typha angustifolia stem counts	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	3	0	0	0.3
Typha x *glauca* stem counts	35	18	33	29	23	14	35	42	35	30	12	17	26	20	22	21	33	23	11	23	22	10	17	10	30	39	24.2
percent covers																											
total percent cover	75	45	95	65	60	45	40	40	60	85	40	60	55	50	35	45	50	70	40	60	20	50	30	25	60	85	53.3
total *Typha*	40	40	70	50	20	10	30	30	55	35	10	35	30	35	20	40	25	15	15	15	10	10	15	8	50	60	29.7
Typha angustifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	2	0	0	0.3
Typha x *glauca*	40	40	70	50	20	9	30	30	55	35	10	35	30	35	20	40	25	15	12	15	10	8	15	6	50	60	29.4
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Carex lacustris	30	0	20	15	45	30	0	3	2	50	25	15	20	10	15	10	15	40	35	50	5	20	3	15	10	25	19.5
Convolvulus arvensis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0.2
Galium trifidum	1	0	0	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0.3
Impatiens capensis	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Iris versicolor	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Lysimachia thyrsiflora	1	1	2	1	1	0	5	4	3	0	0	0	2	0	0	0	1	1	0	0	1	3	2	3	1	2	1.3
Phragmites australis	0	5	10	0	0	10	2	5	0	0	5	15	0	5	0	5	0	15	1	0	8	15	15	0	1	3	4.6
Polygonum amphibium	4	0	0	0	0	1	5	0	5	0	1	0	5	0	0	0	8	10	0	0	0	4	0	0	0	0	1.7
Scuttelaria galericulata	3	0	0	0	1	0	1	2	1	1	0	1	2	0	1	1	2	1	0	1	3	0	1	0	0	1	0.9

Replicate 3 - 8/25/2011																											
	1	2	3	4	5	6	7	8	9	9.1	10	10.1	11	11.1	12	12.1	13	13.1	14	14.1	15	15.1	16	16.1	17	18	Mean
Treatment	**C1**	**C1S**	**C1T**	**C1ST**	**C12**	**C12S**	**C12T**	**C12ST**	**C1W1**	**C1W12**	**C1SW1**	**C1SW12**	**C1W1T**	**C1W12T**	**C1SW1T**	**C1SW12T**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12W12T**	**C12SW1T**	**C12SW12T**	**control**	**control**	
Quad	20	5	14	2	19	8	11	6	9	25	18	12	21	3	4	17	10	1	16	22	24	15	23	26	7	13	
total *Typha* stem count	32	32	39	29	16	5	6	8	36	19	28	21	27	27	30	23	21	20	15	9	8	12	7	5	54	45	22.1
Typha angustifolia stem counts	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0	0.3
Typha x *glauca* stem counts	32	30	39	29	16	5	6	8	36	19	28	21	27	27	30	23	18	20	15	9	8	12	7	5	51	45	21.8
percent covers																											
total percent cover	85	60	90	50	45	25	70	30	85	50	45	40	85	45	35	80	30	15	40	30	60	25	25	70	95	95	54.0
total *Typha*	40	55	40	50	10	1	5	3	70	25	30	30	45	35	35	35	10	15	10	5	10	6	3	2	90	60	27.7
Typha angustifolia	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0	0.4
Typha x *glauca*	40	52	40	50	10	1	5	3	70	25	30	30	45	35	35	35	9	15	10	5	10	6	3	2	85	60	27.3
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	5	0	25	1.2
Carex lacustris	50	2	55	5	30	25	60	30	15	25	15	5	40	10	1	50	10	1	25	20	50	15	20	60	10	25	25.2
Cirsium arvensis	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0.2
Convolvulus arvensis	1	0	0	0	0	0	3	1	0	1	0	2	0	0	0	0	3	0	0	0	2	0	0	3	2	1	0.7
Impatiens capensis	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0.3
Lysimachia thyrsiflora	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0.1
Polygonum amphibium	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0.3
Scutellaria galericulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.0
Teucrium canadense	1	10	1	2	10	4	2	1	5	2	8	5	8	3	5	3	3	1	5	5	2	3	5	2	5	0	3.9
unknown Aster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0
Unknown seedling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.0

Replicate 4 - 8/25/2011																										
	2	2.1	3.1	4	5	5.1	7	8	9	9.1	10	11	11.1	11.2	11.3	12.1	13	13.1	14	14.1	14.2	16	16.1	16.2	17	18	Mean
Treatment	**C1S**	**C1S**	**C1T**	**C1ST-C2**	**C12**	**C12-S2W2**	**C12T**	**C12ST-C2W2**	**C1W1**	**C1W1**	**C1SW1**	**C1W1T**	**C1W12T**	**C1W12T**	**C1W1T**	**C1SW12T**	**C12W1**	**C12W1-S2**	**C12SW1**	**C12SW1**	**C12SW1**	**C12SW1T-C2**	**C12SW12T-S1**	**C12SW12T**	**control-W2**	**control**	
Quad	3	8	10	1	15	4	6	11	14	17	24	5	19	21	25	20	16	12	9	7	26	13	23	18	22	2	
total *Typha* stem count	28	43	33	27	11	38	56	36	13	5	22	30	11	19	9	20	19	20	22	20	25	26	10	12	33	24	23.5
Typha angustifolia stem counts	0	10	0	2	0	4	5	2	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	3	1.2
Typha x *glauca* stem counts	28	33	33	25	11	34	51	34	13	5	22	30	9	19	9	20	16	20	22	20	25	26	10	12	33	21	22.3
percent covers																											
total percent cover	70	65	80	40	85	40	85	55	75	95	80	45	40	85	70	90	85	40	55	55	60	30	85	60	95	90	67.5
total *Typha*	45	45	50	10	5	15	75	30	20	5	25	40	15	40	15	40	10	10	10	15	15	15	5	10	40	35	24.6
Typha angustifolia	0	10	0	1	0	2	7	2	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	4	1.1
Typha x *glauca*	45	35	50	9	5	13	68	28	20	5	25	40	12	40	15	40	8	10	10	15	15	15	5	10	40	31	23.5
Calamagrostis canadensis	15	10	20	20	85	0	0	0	60	85	30	0	10	25	30	0	75	0	35	0	30	0	30	15	30	45	25.0
Carex lacustris	0	0	2	0	0	0	0	5	0	0	25	0	2	25	25	50	0	5	5	0	3	3	25	0	30	0	7.9
Galium trifidum	0	0	0	0	0	1	0	1	0	0	1	1	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0.4
Hydrocharis morsus-ranae	0	1	1	1	0	0	0	1	0	0	0	0	1	1	0	1	0	1	1	0	0	1	0	1	0	0	0.4
Lycopus americanus	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.2
Lysimachia thyrsiflora	0	1	1	1	0	0	2	1	1	0	1	1	1	1	1	1	0	1	0	1	2	0	0	1	1	0	0.7
Phalaris arundinacea	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Polygonum amphibium	15	15	10	10	4	30	10	10	5	15	2	20	20	5	8	1	5	20	10	50	10	15	25	30	5	10	13.8
Polygonum hydropiper	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Rumex spp.	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	1	0	1	0	0	0	2	0	0	0	0.3
Scuttelaria galericulata	0	0	0	2	3	1	0	0	1	0	0	1	2	2	0	2	0	1	1	0	1	1	1	5	0	1	1.0
Teucrium canadense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0.1
unknown 3 (celery)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.0

Replicate 5 - 8/25/2011																											
	1	1.1	2	2.1	3	3	4	8	9	9.1	10	10.1	11	11.1	11.2	12	12.1	13	13.1	14	14.1	15	16	16.1	17	18	Mean
Treatment	**C1**	**C1**	**C1S**	**C1S**	**C1W2T**	**C1T-C2SW2**	**C1ST-W2**	**C12ST**	**C1W1**	**C1W12**	**C1SW1-C2**	**C1SW12**	**C1W1T**	**C1W1T**	**C1W1T-C2S**	**C1SW1T**	**C1SW1T-C2**	**C12W1**	**C12W12**	**C12SW1**	**C12SW12**	**C12W1T**	**C12SW1T**	**C12W12T-S1**	**control**	**control**	
Quad	16	25	23	20	21	1	24	17	8	4	3	14	15	13	26	2	22	19	9	18	10	6	7	12	5	11	
total *Typha* stem count	53	26	32	28	43	22	38	33	20	16	24	17	25	17	20	15	10	24	13	27	23	17	22	13	43	39	25.4
Typha angustifolia stem counts	0	0	0	2	0	3	5	3	0	6	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0.9
Typha x *glauca* stem counts	53	26	32	26	43	19	33	30	20	10	24	17	25	17	20	12	10	24	13	27	23	16	22	13	43	39	24.5
percent covers																											
total percent cover	90	75	50	65	75	45	75	40	30	30	30	55	85	25	30	40	15	50	10	35	10	30	10	25	75	60	44.6
total *Typha*	75	40	50	50	60	10	65	30	30	25	30	25	65	20	25	20	15	35	10	30	10	10	10	15	75	60	34.2
Typha angustifolia	0	0	0	4	0	1	9	3	0	9	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	1.2
Typha x *glauca*	75	40	50	46	60	9	56	27	30	16	30	25	65	20	25	16	15	35	10	30	10	9	10	15	75	60	33.1
Carex lacustris	15	35	1	20	15	30	10	10	0	10	1	30	25	10	7	20	0	15	0	2	0	20	0	10	0	0	11.0
Lemna minor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.0
Lysimachia thyrsiflora	0	1	0	2	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	0.4
Polygonum amphibium	3	1	0	0	0	0	0	0	1	0	3	8	3	2	3	0	0	0	6	4	0	3	0	1	0	8	1.8
unknown 3 (celery)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0.1

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